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EVALUATION OF FIVE WASTE MINIMIZATION TECHNOLOGIES AT THE GENERAL DYNAMICS POMONA DIVISION PLANT

by

PEI Associates, Inc.
Cincinnati, Ohio 45246

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16. ABSTRACT

Five technology areas encompassing eight waste reduction technologies at the General Dynamics Pomona Division (Southern California) were technically and economically evaluated under the California/EPA Waste Reduction Innovative Technology Evaluation (WRITE) Program. Evaluations were made through site visits and follow-up discussions with General Dynamics staff and equipment suppliers.

The technologies and the type of waste reduction represented included (1) computerized printed circuit board plating process (process substitution), (2) sulfuric acid anodizing system (process substitution), (3) robotic paint facility operations - a) proportional paint mixing (process substitution), b) water-based solvent replacement (process substitution), c) electrostatic paint sprays (process substitution), d) solvent stills (recycling), (4) bead-blast paint stripper (process substitution), and 5) Freon recovery stills (recycling).

Overall, there was a decrease in hazardous waste generation and an increase in productivity or reuse of recycled materials. In most cases, the technologies could be easily transferred to other industries except for the computerized circuit board and some processes within the robotic paint operation due to prohibitive costs.

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act.

This report is the first of a series of studies that will present the results of evaluating innovative waste-reduction technologies as a part of the EPA's Waste Reduction Innovative Technology Evaluation (WRITE) Program.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

Eight waste reduction technologies encompassing five industrial process areas at the General Dynamics Pomona Division (GDPD) were technically and economically evaluated under the California/U.S. Environmental Protection Agency (EPA) Waste Reduction Innovative Technology Evaluation (WRITE) Program. Evaluations were made through site visits and follow-up discussions with GDPD staff and equipment suppliers.

The technologies included (1) computerized printed circuit board plating; (2) sulfuric acid anodizing; (3) robotic paint facility operations with (a) proportional paint mixing, (b) water-based solvent replacement, (c) electrostatic paint spraying, and (d) solvent distillation; (4) bead-blast paint stripping; and (5) Freon* recovery.

Overall, there was a decrease in hazardous waste generation and an increase in productivity or reuse of recycled materials. In most cases, the technologies could be easily transferred to other industries except for the prohibitive costs of the computerized circuit board and some processes within the robotic paint operation. The payback period estimates ranged from less than a year for the Freon recovery still to 67 years for the sulfuric acid anodizing system. Difficulties in estimating payback periods resulted mainly from the unavailability of company-sensitive information.

This report was submitted in fullfillment of Contract No. 68-03-3389 by PEI Associates under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from June 1989 to September 1989, and work was completed as of September 1989.

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* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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SECTION 1

INTRODUCTION

This study was performed under the California/EPA Waste Reduction Innovative Technology Evaluation (WRITE) program, and was a cooperative effort between EPA's Risk Reduction Engineering Laboratory (RREL), the Alternative Technology Division within the Department of Toxic Substances Control (DTSC) of the State of California, and General Dynamics Pomona Division (GDPD), whose waste minimization processes are the subject of this report. The overall EPA WRITE Program is described in Reference 1.

General Dynamics Pomona Division builds various tactical defense weapons, primarily air defense missiles, and gun systems. In 1984, General Dynamics established a corporate environmental program with individual Division responsibility for hazardous waste reduction, including reductions in use of toxic substances.

As a result of implementation of this corporate policy, several waste reduction process modifications have been instituted at the Pomona Division. A reduction of 97 percent in the annual discharge of hazardous (about 10,600 tons), liquid, and solid wastes, and a reduction of 95 percent in volatile organic carbon (VOC) emissions (about 17.5 tons) have been reported by GDPD through a combination of waste reduction and treatment technologies.[2,3]

Of the 14 waste minimization technologies recently employed at GDPD, only five process areas encompassing eight technologies were evaluated. The areas included in the study are listed below with the type of waste minimization they represent:

Computerized printed circuit board plating (process substitution/ recycling)

Sulfuric acid anodizing system (process substitution)

Paint facility
- Proportional paint mixing (process substitution)
- Water-based solvent replacement (process substitution)
- Electrostatic paint sprays (process substitution)
- Solvent stills (recycling)

Bead-blast paint stripper (process substitution)

Freon recovery stills (recycling)

Sections 2 through 6 of this report provide the following information for each of these five process areas:

Technology description. Fourteen waste minimization technologies employed at GDPD were screened for technology applicability, source reduction potential, extent of process modification, and cost-effectiveness for inclusion in this study. The following five process areas encompassing eight separate technologies were ultimately chosen for further analysis:

- Printed circuit board plating system
- Sulfuric acid anodizing system
- Paint facility
  - -- Proportional paint mixing
  - -- Water-based solvent replacement
  - -- Electrostatic paint sprays
  - -- Solvent stills
- Freon recovery stills
- Bead-blast paint stripper

Technical/economic evaluation. Technical and economic evaluations were conducted during site visits, and additional information required was obtained through subsequent followup conversations with GDPD staff and system suppliers. As economic objectives were centered around return on capital, internal rate of return, and payback periods which are considered company sensitive information, a simple payback for each process was calculated.

Sampling/analysis. Sampling and analysis procedures and results for the water and air samples were taken to confirm assumptions and/or plant data on waste minimization technology performance. Each process section provides a description of the sampling and analysis procedures and results utilized for this study. Details of these procedures are contained in the Quality Assurance Project Plan for this project.

Overall conclusions for each technology.

The Appendix provides photographs of the waste minimization technologies evaluated.

SECTION 2

PRINTED CIRCUIT BOARD PLATING SYSTEM

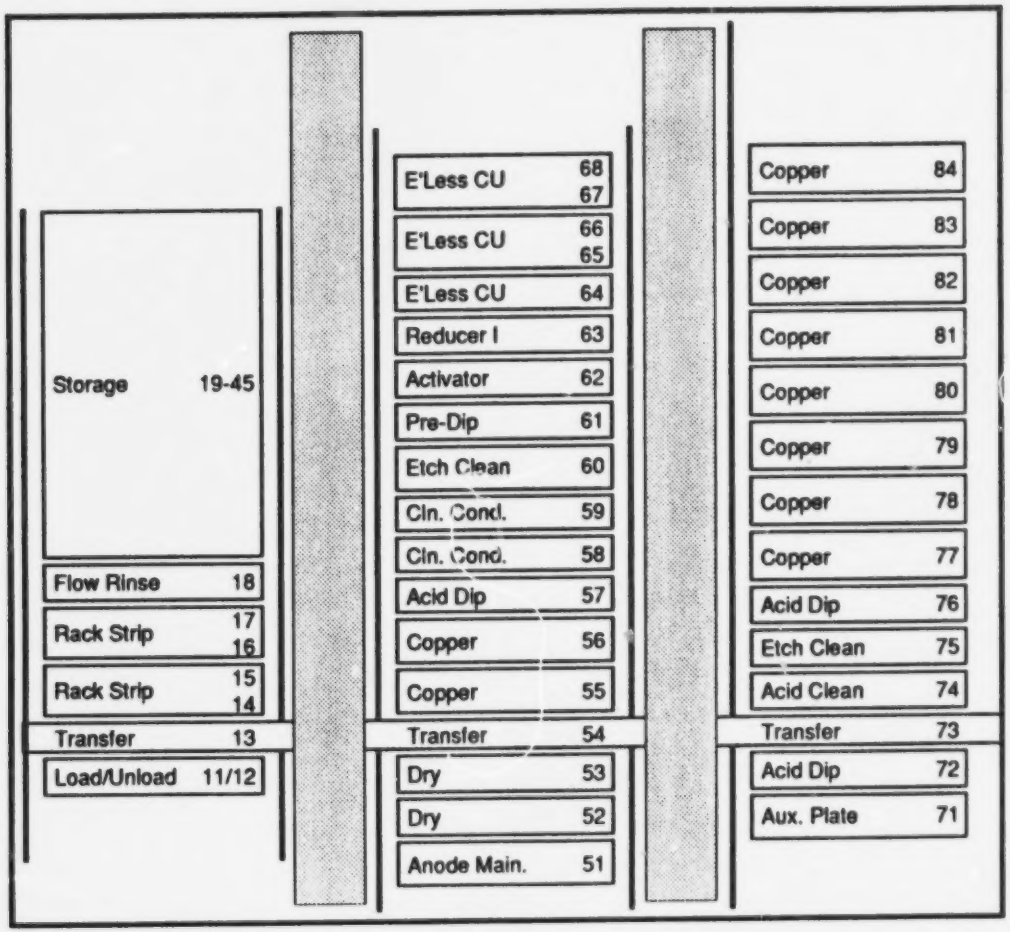
TECHNOLOGY DESCRIPTION

Chemcut Corporation installed a new computerized printed circuit board plating system at General Dynamics in July 1988, at a cost of $4,100,000. Figure 2-1 shows the tank configuration layout of the printed circuit board system, and Table 2-1 presents the standard operating sequence for the process. This new plating system completely eliminated rinse tanks from the process by use of a unique spray-rinse system contained in a transporter hoist system that passes over the plating bath tanks. This computerized hoist system, allows the circuit boards to be rinsed for only a short duration after their immersion in a process solution. Rinse water discharge from this new process is less than 10 gallons per minute (gpm) versus 60 gpm from the old process. This reduction in wastewater discharge allowed for a corresponding reduction in metal recovery system sizing. The use of a spray rinse versus a dip rinse can also be a major design factor if water supply limitations must be considered, or if there are floor space limitations.

Copper spheres in anode baskets are used in the new system instead of the conventional anode bar-and-hook system that was utilized in the old plating system. This allows a 1 to 1 ratio of anode to cathode for a very even plating across the panel and through the holes.

In conjunction with the installation of the new production equipment, Chemcut Corporation was required to provide a non-sludge-producing treatment system for all waste streams generated by the process. This resulted in the installation of a new copper-recovery system in which short-bed ion-exchange columns and electrowinning technologies are used. This system now produces salable scrap copper metal, eliminating a major waste stream to the conventional sludge-producing waste treatment system.

Figure 2-2 shows a flow diagram of the printed circuit board copper recovery system. The copper recovered with this process represents the equivalent of approximately 365 tons of sludge that would have had to be disposed of in a landfill.



E'Less CU = Electroless Copper
Cln. Cond. = Cleaner/Conditioner

Figure 2-1. Tank configuration of printed circuit board system.

TABLE 2-1. OPERATION SEQUENCE FOR PRINTED CIRCUIT BOARD SYSTEM

Position	Step
11	Load
58	Cleaner/conditioner
59	Cleaner/conditioner
60	Etch cleaner
61	Predip
62	Activator
63	Reducer
65-66	Electroless copper
57	Acid dip
76	Acid dip
77-83	Acid copper plating
53	Dry
51	Hold
11	Unload

TECHNICAL/ECONOMIC EVALUATION

Objectives

The objectives of the computerized printed circuit board plating operation evaluation include the following:

1) Verification of reductions in wastewater rinse flow by comparing records of present wastewater flows vs. previous wastewater flow data. Wastewater flows were to be checked during the plant visit.

2) Establishment of a material balance around the printed circuit board process, if possible, using available plant data. Transport of copper-bearing waste streams to their appropriate metal recovery processes were to be documented and sampled for metal concentrations. Samples were to be taken from the holding tanks that feed into the non-complexed and complexed ion exchange columns (2 samples). These samples represent composites of the spray rinses from the printed circuit board operation. A third sample was to be taken of the combined outlet stream from the non-complexed and complexed ion exchange units. Information on the fate of metals from the previous plating operation was to be obtained for comparison with the new process.

   Air emissions above the baths were expected to be negligible and no air sampling was planned.

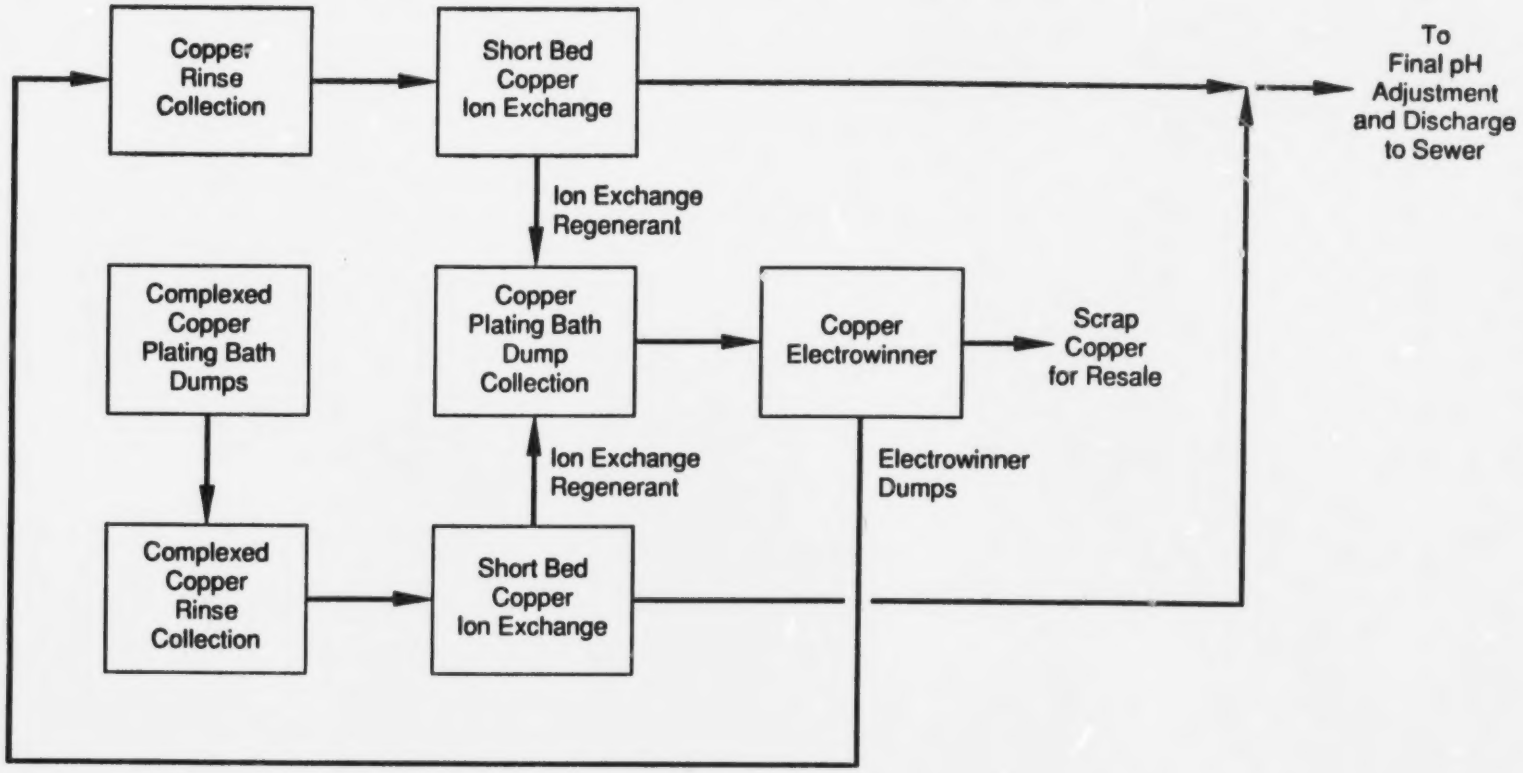


Figure 2-2. Flow diagram of a circuit board copper recovery system.

3) Investigation of the transferability of the use of copper spheres in anode baskets to other electroplating operations. The copper spheres decrease in diameter and fall to the bottom of the basket as they are used up while new spheres are inserted on top of the used spheres. Savings in sampling costs from the use of this system vs. the old system of sampling anode thickness to determine replacement of anodes were to be documented, and an economic analysis (capital, annual costs/credits and payback) of retrofitting the baskets onto another plating process was planned based on input from plant personnel and the anode basket manufacturer.

Technical Results

Reductions in rinse-water discharges were verified during the plant visit by checking rinse-water flow rates via General Dynamics operating logs. Establishing a material balance around the printed circuit board process was not possible from information available from plant personnel, operating data, or system suppliers. This is due to the use of the proprietary process chemistry, developed overseas by Schering AG West Germany, the parent company of the system supplier, Chemcut Corporation. With respect to the fate of metals from the previous plating operation, rinse-water wastes containing copper were simply sent to the on-site waste treatment plant for metals precipitation. The sludge was then sent off site for landfill disposal. Currently, the copper is recovered using ion-exchange and electrowinning equipment. Sludge disposal from this process has been eliminated.

Vendors and trade associates were contacted to ascertain the transferability of the use of copper spheres in anode baskets used by General Dynamics to other electroplating operations. According to representatives of Chemcut Corporation and the American Electroplating and Surface Finishers Association, anode baskets for electroplating have been in commercial use for 25 to 30 years. Anode basket plating is preferred over the old conventional anode bar-and-hook type due to the following advantages:

Constant anode surface area (promotes uniform plating on parts)
Less product waste

Improved handling of anode material (anode material can be added without shutting down plating process)

No wasted anode material (anodes can be allowed to dissolve, completely eliminating the need to recycle unused anode material)

Easier to maintain proper current density (presence of the basket and the constant anode surface area aids in maintaining current density)

Anode baskets can be filled using a variety of shaped anode material, including balls, pellets, chips, bars, etc. Anode balls are usually preferred over the other shapes due to the following advantages:

Easier to maintain proper current density.

Avoids bridging caused when anode material does not settle in basket (would cause nonuniform plating).

Lack of bridging allows for the use of deeper baskets (larger parts can be plated more easily).

Less anode material per basket due to increased surface (area allows for lighter baskets and easier handling).

Anode balls can be used in other metal-plating operations, including nickel, zinc, and tin. According to the Connecticut Association of Metal Finishers, the conversion of anode bar plating to anode basket plating has taken place and was already present in the metal-finishing and printed circuit board industries. The main driving force for the conversion was again the ability to achieve uniform plating on a continuous basis. This helps to lower operating labor costs and costs associated with product rejections. The costs to retrofit baskets to an existing bar-plating tank were reported to be reasonable. According to Cosmos Minerals, a supplier of titanium anode baskets, converting from the anode bars to anode baskets simply requires the purchase of the baskets. No changes to the plating bath tank and associated equipment are usually required. The baskets are hung from the same hooks used to support the old anode bars. The baskets, depending on the shape, size, screen opening, and materials of construction, range in price from $50 to $120 each. For example, a tank requiring the installation of 30 baskets would cost only $1500 to $3600.

During the plant visit, General Dynamics reported problems with having to remove the anode ball material once per month to have the balls etched (i.e., cleaned). According to a Chemcut representative, the current density was too high and the anode balls formed a nonsoluble copper salt surface coating, rendering them passive. Current density is the average current in amperes divided by the area through which the current passes. Current density too high at the anode renders it passive, and current density too low causes the metal to dissolve in an unwanted valence state. Other factors being equal, the higher the current density obtainable, the faster the plating rate, and thus, in general, the more economical the operation. It was determined that the current density was high because the anode balls were too large in diameter, and subsequently did not provide an adequate amount of anode surface area. The Chemcut representative recommended the problem be solved by either using smaller diameter balls or adding baskets. Both of these approaches would help to increase the anode surface area, and thus lower the current density.

Economic Evaluation Results

As presented in Table 2-2, cost savings in labor and waste treatment were found to be the major cost parameters, resulting in a favorable net annual operating savings between the original and newly installed printed circuit board plating systems. The payback period for the printed board plating system was estimated to be 8.3 years.

TABLE 2-2. ECONOMIC EVALUATION OF PRINTED CIRCUIT BOARD PLATING OPERATION WITH ON-DEMAND RINSING[a]

Economic data		
Annual operating costs of old process		
Anode replacement	$ 65,000	
Chemical replacement	138,000	
Labor	499,000	
Water	12,000	
Total		$ 714,000
Annual operating costs of new process		
Anode replacement	46,000	
Chemical replacement	125,000	
Labor	175,000	
Water	2,000	
Total		$ 348,000
Waste treatment savings		$ 130,000
Net annual operating savings		$ 496,000
Capital investment		$4,100,000
Payback period		8.3 years

[a] Based on plant operation of 2 shifts per day, 8 hours per shift, 6 days per week.

Due to lack of computer automation, operation of the original system required six employees (i.e., four hourly and two engineers), versus two employees (i.e., one hourly and one engineer) for the new system. This resulted in a cost savings in labor of $324,000 based on the plant operating two shifts per day, 8 hours per shift, and 6 days per week.

The cost savings in waste treatment of $130,000 represents the savings resulting from the recovery of copper from rinse water and process tank solutions, which were previously treated and disposed of as hazardous sludge. Copper is now recovered as a salable by-product using ion-exchange and electrowinning equipment. The recovery process, estimated to be approximately 15 percent of the total capital installed cost of the printed circuit board system, produces solid slabs of copper which weigh approximately 30 pounds. One copper slab represents an equivalent of 0.5 tons of sludge that previously required landfill disposal at a cost of $1200. Now, the recovered copper has a by-product value ranging from $15 to $20 per slab.

The anode and chemical replacement costs shown in Table 2-2 for the new plating system are 50 percent of the actual General Dynamics reported figures. These operating costs were reduced to compensate for the fact that the new process has double the operating capacity of the older system. However, these adjusted anode and chemical replacement costs for the new plating system may decrease further by the time start-up is complete and chemical substitutions have been made. Problems with achieving the proper current density across the plating tank made it necessary to have anode material etched (i.e., anode balls had become passive, making it necessary to clean the outer surface of the anode). The amount of anode ball material in the tank was also modified to adjust the tank current density. Both of these operations have resulted in more efficient anode use. Chemical replacement costs should also decrease once steady-state continuous operations are reached. Presently, General Dynamics is required for warranty reasons to use the proprietary chemistry made in Germany.

A cost savings for water usage was estimated to be $10,000 based on a net overall decrease in rinse-water discharges of 50 gpm. The decrease in usage was due to the use of automated hoists and on-demand spray-rinse systems. The savings was estimated assuming full-time operation (i.e., 4992 hours per year) and the Pomona City Water Works water rate of $0.65 per 1000 gallons.

General Dynamics determined the original antiquated system could not have economically been modified to meet desired production rates and waste reduction goals.

SAMPLING/ANALYSIS

Printed Circuit Board Operation

Transport of copper-bearing waste streams to and from the complexed and noncomplexed copper ion exchange recovery processes was documented by sampling for copper and the following other selected metals: chromium, cadmium, nickel, zinc, silver, lead, and aluminum. Plant records on copper concentrations to and from the copper ion exchange processes were reviewed during the site visit as the basis for comparing the sample results. Figure 2-3 illustrates the sampling locations for this process.

Table 2-3 presents the results of the metals samples for the complexed and noncomplexed copper feeds and the combined outlets from the complexed and noncomplexed copper feed outlets, compared with available data on copper concentrations for the same sampling points from plant records.

The results of the sampling showed reasonable agreement between the PEI data (118 mg/liter) and the GDPD plant records (199 mg/liter) for the non-complexed copper feed. No GDPD data were available for the complexed copper feed, which predictably showed much lower copper concentrations (5 mg/liter) in the PEI sample. The combined outlet from both ion exchange units showed 0.2 mg/liter in the PEI sample, compared with an average of 0.6 mg/ liter from GDPD plant records.

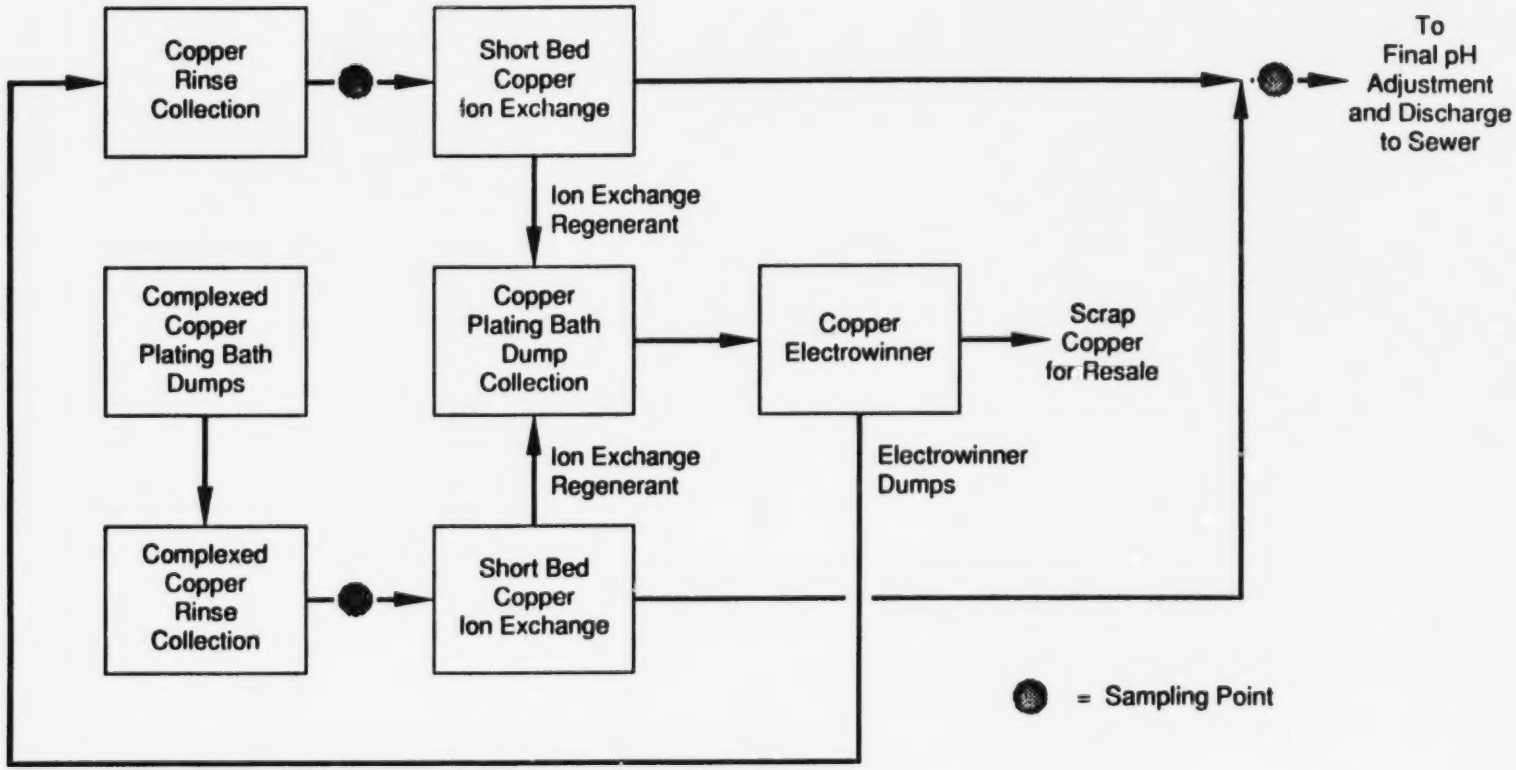


Figure 2-3. Sampling points for the Printed Circuit Board Process.

The concentrations of all other metals tested were very low, with the exception of zinc in the noncomplexed copper feed, which was about 40 mg/liter. The reason for this high concentration of zinc is not known; since data on the proprietary chemistry of the bath solution was not available, no effort was made to determine the cause.

TABLE 2-3. COMPARISON OF METALS CONCENTRATIONS FROM PRINTED CIRCUIT BOARD METAL RECOVERY SYSTEMS (mg/liter)

	Noncomplexed copper feed		Complexed copper feed		Complexed/non complexed outlet		Combined Method detection limit
Metal	PEI	GDPD[a]	PEI	GDPD	PEI	GDPD[b]	
Copper	118	199	5.31	-	0.20	0.6	-
Aluminum	0.24		0.058		0.17		<0.024
Cadmium	<0.003		<0.003		<0.003		<0.003
Chromium	0.12		0.079		0.054		<0.004
Lead	0.14		<0.052		<0.052		<0.052
Nickel	0.12		0.036		<0.031		<0.031
Silver	0.012		<0.006		0.010		<0.006
Zinc	39.8		0.15		4.54		<0.006

[a] Average of nine observations.
[b] Average of four observations.

Wastewater Treatment Plant Outlet

A sample for metals was taken of the total plant wastewater treatment plant effluent before it is discharged to the sewer. This sample was then checked against data provided by GDPD. The results of this sample are presented in Table 2-4.

This comparison indicated that the PEI sample predictably showed lower values for most metals than the 3-year composite from GDPD data. As shown in Table 2-4, however, some of the metals from the GDPD data have decreased in the period 1986 to 1989, bringing them closer to the PEI sample results. The one exception was zinc, which at 0.35 mg/liter, is very low, but much higher than the 0.07-mg/liter value recorded by GDPD. All of these values are well below wastewater discharge limits for metals from California metal finishing operations.

TABLE 2-4. COMPARISON OF PEI METAL SAMPLE OF PLANT WASTEWATER DISCHARGE WITH GDPD PLANT DATA
(mg/liter)

Metal	PEI sample	GDPD[a]	GDPD[b]	Method detection limit
Aluminum	0.35	-	-	0.024
Cadmium	<0.003	0.04	0.01	0.003
Chromium	0.019	0.27	0.04	0.004
Copper	1.59	1.49	0.98	0.020
Lead	<0.052	0.11	0.30	0.052
Nickel	<0.031	0.07	0.07	0.031
Silver	<0.006	-	-	0.006
Zinc	0.36	0.06	0.06	0.006

[a] Average of 11 quarterly composites for the period 1/86 to 4/89.
[b] Composite average for period 1/89 to 4/89.

Quality Control

Although the samples taken were not considered to be critical to the outcome of the evaluation, limited quality control samples were analyzed. The results of matrix spike/matrix spike duplicates (MS/MSD's) for the combined ion exchange outlet samples are presented in Table 2-5. All of the percent recoveries were within the 75 to 125 percent recovery target range.

TABLE 2-5. QUALITY CONTROL RESULTS FOR PRINTED CIRCUIT BOARD METALS SAMPLE MD/MSD's
(% recovery)

	Complexed/non-complexed copper combined ion exchange outlet	
Metal	MS	MSD
Aluminum	96.1	95.6
Cadmium	87.5	87.2
Chromium	96.5	96.9
Copper	89.7	89.3
Lead	85.3	86.3
Nickel	88.8	89.7
Silver	82.6	84.2
Zinc	75.4	78.7

CONCLUSIONS

A material balance was not able to be developed for the system because not enough data was available due to the company sensitive nature of the information. The reduction in water usage, however was verified as was data on copper concentrations into and out of ion exchange columns used to recover copper from the process. Sludge disposal has virtually been eliminated.

The use of anode baskets, although common practice for new systems in the electroplating industry because of superior current density capability (thus lowering labor costs and product rejects) and other advantages, could easily be retrofitted into existing systems that still utilize anode bars. Start up problems caused by too high a current density resulted in having to remove the anode balls to etch them and restore their reactivity. This was judged to be a short term problem and readily solvable by reducing the size of the anode balls.

Cost savings in labor, waste treatment and water usage resulted in a net operating savings when compared to an estimate of the operating cost of the old plating system. This savings may increase with time as a result of start-up problem resolution and reductions in chemical costs. Although a payback of 8.3 years was calculated on the capital investment of $4.1 million, this does not consider the fact that a retrofit of the old system to the present operating capacity and waste reduction goals would have resulted in even higher capital costs. Looking at the expenditure from this standpoint, it could be reasoned that the new system is providing an instant payback because of lower capital costs and operating cost savings. Transfer of this type of computerized plating technology to smaller companies, however, would be difficult because of the high overall capital costs.

SECTION 3

SULFURIC ACID ANODIZING SYSTEM

TECHNOLOGY DESCRIPTION

In December 1988, General Dynamics replaced its 35-year-old chromic acid aluminum anodizing system with a new computerized sulfuric acid anodizing system which utilized computerized hoists and on-demand rinsing. The new system, supplied by NAPCO, Inc., enabled General Dynamics (GD) to eliminate a major source of chromium emissions.

Anodizing of aluminum involves the formation of an aluminum oxide film on an aluminum surface by electrochemical means. The aluminum serves as the anode, and the oxygen is provided by the electrolytic dissociation of water. The oxide film produced provides an excellent barrier against corrosion. The three principal types of anodizing used by industry today are chromic acid anodizing (referred to by industry as Type I anodizing); sulfuric acid anodizing (referred to by industry as Type II anodizing); and hard anodizing, a patented process that uses a combination of sulfuric and oxalic acids as the electrolyte (referred to by industry as Type III anodizing). In addition to increasing corrosion resistance, anodizing also increases paint adhesion characteristics, making subsequent painting possible, improves the appearance, provides electrical insulation, and aids in the detection of surface flaws.

General Dynamics used chromic acid in the original aluminum anodizing process because it was called for in their military contract specifications. Typically, the much less corrosive chromic acid process is used when parts are either subject to stress or contain blind holes (e.g., trapped areas, recesses, porous castings) in which anodizing solution could be entrapped. The use of chromic acid anodizing also made it easier to detect fine surface flaws (e.g., cracks in metal surface) on finished parts. For these reasons, the chromic process, which has higher operating costs than the other anodizing processes, is typically used by the aerospace industry, the military, and military contractors. After completing about 3000 hours of salt-spray corrosion testing, General Dynamics was permitted to change from chromic acid to sulfuric acid anodize. Although the military required only 336 hours of testing for the changeover, General Dynamics wanted to assure that the final product performance would equal or exceed the chromic acid anodize performance.

Besides the chemical substitution to eliminate chromium releases, the addition of automated hoists and on-demand water rinse system helped to reduce wastewater treatment requirements. The computerized automated hoists monitor the time intervals during which the parts are treated and allowed to drain.

Compared with manual immersion and draining of the parts, this system reduces treatment requirements by avoiding unnecessary dragout of immersion fluids to downstream rinse tanks. Subsequently, the on-demand water rinse system reduces rinse-water usage and wastewater treatment requirements by reducing water consumption and monitoring the conductivity of the rinse water in the tank. Unlike manually operated rinse tanks, which have constant overflows, the on-demand system adds water only when the conductivity of the tank exceeds a set value. By using this on-demand water process, rinse water requirements were reduced from 15 and 20 gallons per minute (gpm) to 6 and 8 gpm. Spray rinsing is an alternate approach to on-demand immersion rinse; however, this case required immersion rinsing due to complex and variable parts configuration.

TECHNICAL/ECONOMIC EVALUATION

Objectives

The new automated sulfuric acid anodizing system with on-demand rinsing was installed in December 1988 to replace a 35-year-old chromic acid anodizing system. The capital cost of the new system, which eliminated both water and air emissions of chromium, was $955,000. The objectives of the evaluation included the following:

1) Analysis of the impact of computerized control on product quality in transferring the technology to other facilities; how much better quality control does it provide than conventional sulfuric acid anodizing systems?

2) Establishment of a material balance around the process. Effluent from the deoxidation/desmut rinse tank (which has the greatest potential of all of the rinse tanks to contain metals). Ambient air above the bath was expected to show negligible amounts of acid vapors based on previous sampling of nearby conversion coating tanks; thus, no air sampling was planned. These data were to be compared with available plant data on wastewater and air emissions for the old chromic acid process.

3) An economic analysis of the sulfuric acid anodizing process was to be attempted using data supplied by the plant. Annual operating costs and savings from elimination of chromium disposal and payback for the new system were to be calculated.

Technical Results

Vendors were contacted to ascertain the impact of computerized control on product quality and whether this technology was transferable to other electroplating industries. According to representatives of the Walgren Company, one of the largest designers and suppliers of anodizing equipment, there are two levels of computerization available in the metal-finishing industry. The first level involves the use of computer-controlled automated hoists. This type of computerization has been available for several years in

the metal-finishing industry. Computerized hoists, as compared with manual immersion and draining of parts, reduce rinse water and downstream waste treatment requirements by avoiding unnecessary dragout of immersion fluids. Product quality and the number of part rejections are also improved.

The second level of computerization involves the automation of chemical and physical process parameters. This system is capable of sample retrieval from several process baths, performing the required chemical analysis, calculating the amount of feed material needed (if any), and activating a chemical feed system to provide the necessary amount of material needed. This system is also capable of continuously monitoring and automatically controlling physical process parameters such as bath temperatures, rinse water quality, voltage, and current density. This level of computerization by a single system has been in development for the past 10 years and has been made available commercially within the last 2 years. The advantages include lowered labor costs (i.e., less laboratory personnel and machine operators), improved worker safety, improved productivity, improved product quality, lowered chemical usage, lowered production wastes, and process waste minimization. According to Walgren representatives, the system is transferable to all metal-finishing industries. The system could also be utilized in other applications such as controlling paint lines and waste-treatment systems.

Establishing a material balance around the sulfuric acid anodizing system was not possible from the information made available from plant personnel and operating data. In addition, no information was available concerning wastes generated from the old chromic acid system. Therefore, vendor information was utilized to approximate certain operating costs, the savings from elimination of chromium disposal, and payback. This information is presented later in this section of the report.

Economic Evaluation Results

The capital cost of the new sulfuric acid anodizing system installed by NAPCO, Inc., for General Dynamics in December 1988 was $955,000. This cost included the computerized hoist and on-demand anodizing rinse systems. Actual operating and maintenance (O&M) cost data were not available from General Dynamics due to the company sensitive nature of the information. However, by understanding the differences between the sulfuric and chromic acid anodizing processes, O&M costs were derived by PEI using information obtained from outside equipment vendors. Using this information, PEI was able to perform an economic analysis of the sulfuric acid aluminum anodizing process. The results of the economic evaluation are presented in Table 3-1. The payback period for the sulfuric acid anoziding system was estimated to be 67 years.

Conversion to sulfuric acid anodizing from chromic acid is not just a simple chemical substitution according to system suppliers. The conversion requires a complete changeover of anodizing equipment and partial modifications to downstream waste-treatment facilities. Capital costs would be realized for such major production equipment items as the anodizing tank,

TABLE 3-1. ECONOMIC EVALUATION OF SULFURIC ACID ANODIZING PROCESS

Economic data		
Annual operating costs of chromic acid process		
Electric (116,000 kWh/yr)		$ 16,200
Water (6 x 10^6 gal/yr)		3,900
	Total	$ 20,100
Annual operating costs of sulfuric acid process		
Electric (38,000 kWh/yr)		$ 5,300
Water (2.4 x 10^6 gal/yr)		1,600
	Total	$ 6,900
Waste reduction savings		$ 1,000
Capital investment		$955,000
Payback period		67 years

rectifier, and cooling equipment. Replacement of the anodizing tank is required due to the differences in acidity between sulfuric acid and chromic acid. Because sulfuric acid is much more corrosive than chromic acid, the materials of construction of the anodizing tank must be upgraded. Because the chromic and sulfuric acid anodizing processes have different voltage and amperage requirements, the rectifier must also be replaced. The operating temperature of the electrolytic bath is also different for the two processes. The chromic process is usually maintained by steam heat at an operating temperature of 90° to 100°F, whereas the sulfuric acid process must be chilled using cooling water to an operating temperature range of 45° to 70°F. Other capital costs, such as adding computerized hoists and on-demand rinse operations, must also be addressed if not present on the existing process. For General Dynamics, it was more cost-effective to completely replace the existing chromic acid process than to make all of these modifications.

The costs associated with testing in order to obtain military approval to modify design specifications were not addressed in the economic evaluation. This information was considered company sensitive by General Dynamics.

O&M costs are typically much lower for sulfuric acid anodizing than for chromic acid because it is less energy-intensive, it has a smaller plating interval, and wastewater treatment costs are less.

Because sulfuric acid is much more conductive as an electrolyte, the anodizing process usually requires less power than that required by the chromic acid process. Specific electrical energy requirements for aluminum anodizing are shown in Table 3-2. As shown in Table 3-1, a cost savings for electricity was estimated to be $10,900. This was based on an annual decrease in electrical consumption of 78,000 kWh. The savings was based on a conventional sulfuric acid usage rate of 130 Wh/m^2 and a chromic acid

TABLE 3-2. SPECIFIC ENERGY REQUIREMENTS FOR ALUMINUM ANODIZING

Type of anodizing	Voltage	Electrical energy, Wh/m^2
Sulfuric acid		
Conventional	12-22	70-130
Hard	25-80	150-480
Chromic acid	30-50	240-400

anodizing usage rate of 400 Wh/m^2. The amount of material anodized was based on the maximum design capacity of the new system (i.e., 625 ft^2/h) and full-time operation (i.e., 4992 hours per year). The cost for electricity (i.e., $0.14/kWh) for a typical industrial consumer was obtained from Southern California Edison Utility Company.

As mentioned earlier, the sulfuric acid process is much faster acting than chromic acid; less process time is typically required for a given film thickness. This results in lower operating costs because the process is more efficient. However, no cost savings could be quantified by PEI concerning increased productivity.

Wastewater treatment costs are less for sulfuric acid than for chromic acid because of a decrease in metals removal requirements. The chromic acid process requires the reduction of chrome, whereas the sulfuric acid process requires only copper removal. Chrome reduction usually requires additional tanks and chemicals for treatment and settling. The sludge from the chromic acid anodizing process is also considered hazardous and must be sent to hazardous waste landfill at a cost greater than that required for the disposal of the sludges produced by the sulfuric acid process. The annual cost savings resulting from decreased sludge disposal requirements was estimated to be $1000, based on an annual usage of approximately 2000 pounds of chromic acid anhydride by General Dynamics. The resulting sludge produced from the use of this chemical, assuming a 25 percent solids composition, would be approximately 4 tons. General Dynamics is presently charged $250 per ton for sludge disposal. The company has a contract with a smelter in Arizona which recycles their plant sludge for its intrinsic copper value. Because other hazardous metals from other plant processes are still contained in the resulting sludge which is sent to the copper smelter, no cost break for landfill disposal could be given for the sludge from the new sulfuric acid anodizing system.

Additional cost savings can be realized with the addition of computerized hoists and on-demand rinse systems. Both of these systems help to reduce water consumption. According to General Dynamics, rinse-water consumption was reduced from 20 to 8 gpm. The cost savings in reduced water consumption was estimated to be $2300, assuming full-time operation (i.e., 4992 hours per

year) and the Pomona City Water Works rate of $0.65 per 1000 gallons. General Dynamics also expects that the computerized hoist system will lower costs associated with rejects and rework.

General Dynamics determined the original 35-year-old chromic acid anodizing system could not be cost-effectively modified to meet current and future air and water regulatory requirements. The company found no technology was available to meet a future requirement to achieve a 99.8 percent removal efficiency for chrome discharged to the atmosphere from their plating process. In addition, the company needed to maintain compliance with the California Safe Drinking Water and Toxic Enforcement Act of 1986. This law prohibits an industry from discharging detectable levels of hazardous chemicals, including chromium, into any source of drinking water. Since the industrial wastewater is discharged to a local Publicly Owned Treatment Works (POTW) which then uses the treated effluent for irrigation purposes, there was a concern with compliance and potential liabilities.

SAMPLING/ANALYSIS

Effluent from the deoxidation/desmut rinse tank was chosen for sampling, since it has the greatest potential of all of the rinse tanks to contain metals. The sample taken represents a composite of the rinses performed in the deoxidation/desmut tank. The rinse water from this and other rinse tanks in the anodizing process undergoes pH adjustment and is sent to the wastewater treatment plant to remove any metals remaining in the rinse water.

The results of the deoxidation/desmut rinse-tank sampling are shown in Table 3-3.

TABLE 3-3. RESULTS OF METAL SAMPLES TAKEN FROM THE DEOXIDATION/DESMUT TANK OF THE H_2SO_4 ANODIZING PROCESS (mg/liter)

Metal	Deoxidation/desmut rinse tank	Method detection limit
Aluminum	14.0	<0.024
Cadmium	<0.003	<0.003
Chromium	0.034	<0.004
Copper	<0.020	<0.020
Lead	0.058	<0.052
Nickel	0.045	<0.031
Silver	0.008	<0.006
Zinc	<0.006	<0.006

As expected, the only metal of any consequence in the deoxidation/desmut tank rinse water was aluminum at 14 mg/liter. Subsequent analysis of the wastewater treatment plant effluent shows a reduction to 0.35 mg/liter.

Quality Control

Results of MS/MSD's for the sulfuric acid anodizing tank samples are presented in Table 3-4. All of the percent recoveries, with the exception of aluminum, were within the 75 to 125 percent recovery range.

TABLE 3-4. QUALITY CONTROL RESULTS FOR SULFURIC ACID ANODIZING TANK METALS SAMPLES

MS	MSD
51.0	61.7
88.2	90.9
92.8	94.2
90.3	92.1
88.1	91.1
90.6	91.8
100.7	97.9
91.4	95.6

CONCLUSIONS

Material balance calculations were not possible from the data provided by GDPD and system suppliers. The automated system has resulted in reduced rinse water, downstream waste treatment requirements, and improved product quality through reduced part rejections. Computerization of the system can be extended to the chemical and process parameters, thus further reducing labor costs, chemical usage, waste products, and further improving product quality. An analysis of the cost of computerization vs. waste reductions and cost savings would provide more insights on its transferability to other processes.

Although operating costs for the sulfuric acid system were determined to be about $15,000 lower than the old chromic acid process, payback on the capital cost of $955,000 was calculated at 67 years. The minimal cost savings (about $1000 according to GDPD) from not having to dispose of chromium waste did not help much in the simple payback calculation.

Again, the payback period for this process may be misleading since GDPD did not believe that they could meet the 99.8 percent removal efficiency requirement and were concerned about discharge of chromium in view of the 1986 California Safe Drinking Water Act. Given that compliance with both air and water regulations would not be possible with available control technology even at higher costs than that for the sulfuric acid system, the capital cost expenditure becomes less important. All chromium emissions are eliminated and there are operating cost savings over the previous system. Viewed from this perspective, the process yields an instant payback. Although this type of automated process substitution could be transferred to smaller companies, the high capital cost could be prohibitive unless chromium disposal costs were high enough to decrease the payback time to a reasonable level.

SECTION 4

PAINT FACILITY

TECHNOLOGY DESCRIPTION

The General Dynamics paint production operations facility was completed in December 1988, to replace manual mixing and hand-spraying of metal parts in naval weapon systems. It includes computer-controlled robots (a GRI OM 5000 unit), which allows quick, automated precision painting. A proportional paint mixer was also added, which feeds preselected quantities of individual paint components directly to the paint spray nozzle eliminating batch makeup operations. Electrostatic spray guns and automatic waste cleaning solvent collection systems were also introduced to allow for recycle and reuse of waste paint. Spray paint booths are also available for touchups. Stills are used for recycling paint cleaning solvents. Figure 4-1 is a schematic of the robot paint facility.

The painting facility uses both water-based primer and oil paints. For oil-based paints, polyurethane thinner is used for paint thinning and equipment cleaning. A thinner containing isopropyl alcohol and xylene is used with water-based primer. Paint waste was reduced from about 42 tons in 1987 to 31 tons in 1988,and were further reduced to 17 tons in 1989. About 1000 gallons of polyurethane cleaning solvent per year is now being recycled through the paint shop solvent stills, resulting in approximately 60 to 100 pounds of still bottoms per week, or about 5,000 pounds per year. The still bottoms and waste paint are sent offsite for incineration.

TECHNICAL/ECONOMIC EVALUATION

Objectives

The objectives of the paint facility evaluation included the following:

1) Determination of the amount of batch paint waste saved by the use of the proportional paint mixing by reviewing plant records on paint waste disposal in past years.

2) Verification of increased transfer efficiency of the electrostatic spray nozzles, which was estimated to have increased from 35 to 65 percent. This was to be done by reviewing plant records on paint use before and after installation of the electrostatic spray guns.

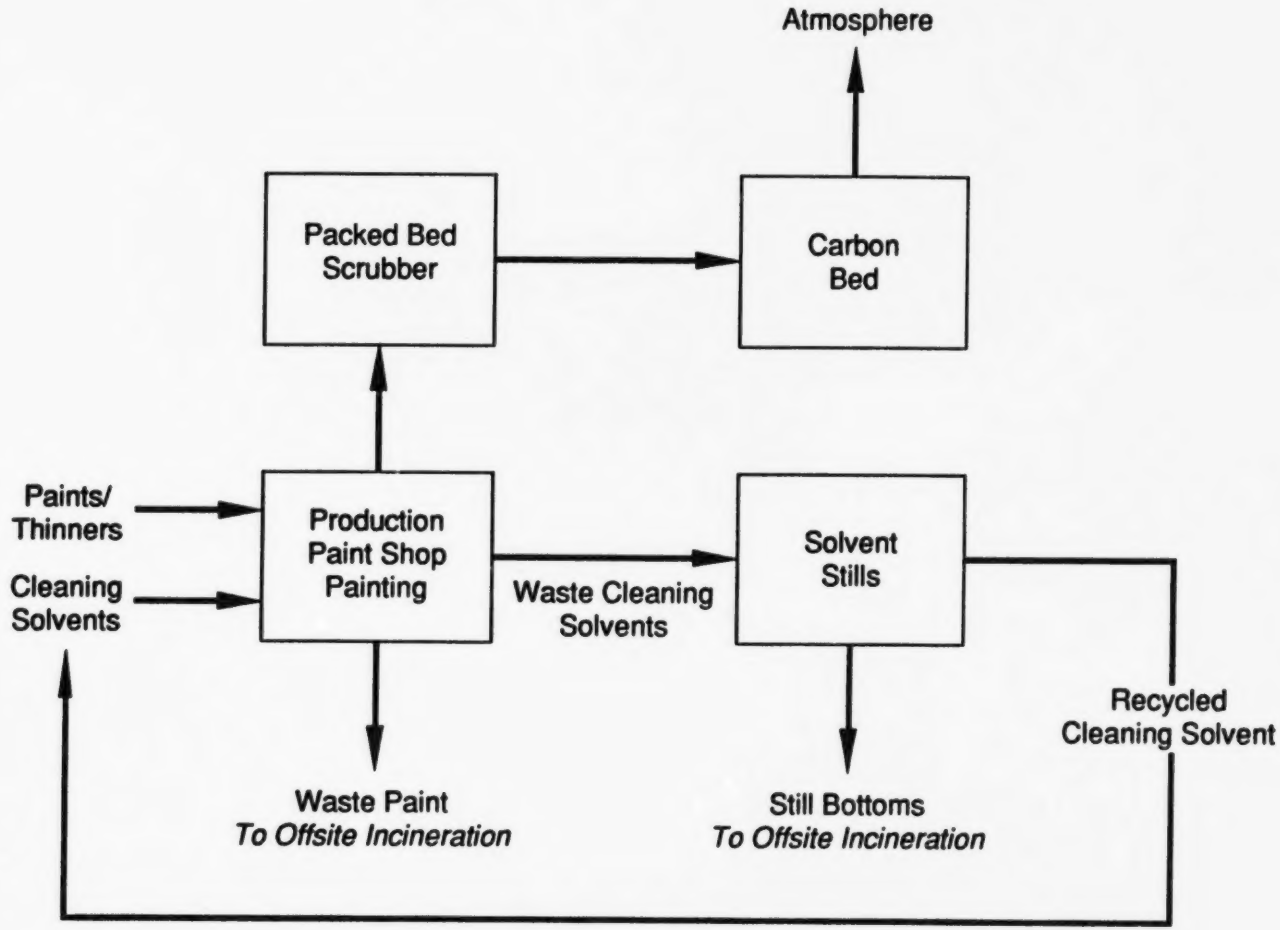


Figure 4-1. Schematic of production paint shop painting/recycling operations.

3) Determination of the amount of solvent reclaimed through the use of the solvent stills by reviewing plant records on solvent purchases and dirty solvent sent off site for recycling before and after installation of the solvent stills. Costs for disposal of the dried paint sludge were also to be determined based on plant records on volume of sludge incinerated.

4) Verification of low concentrations of VOCs in the general area around the paint shop by taking air samples. Three air samples using Tenax and Tenax Charcoal tubes in series were planned to characterize the paint shop area.

5) An economic analysis of the proportional paint mixing electrostatic spray and paint shop solvent still portions of the robotic paint system, was planned.

Technical Results

A breakdown of batch paint waste saved by increased transfer efficiency, proportional paint mixing, water-based primers, or solvents was not possible from the information available from the plant. Transfer efficiencies were not experimentally determined, and detailed records of solvent and paint usage were not readily available. Paint purchases, however, did decrease from 6528 gallons in 1988 to a projected 5,230 gallons in 1989 (based on purchases for the first 6 months) and solvent purchases decreased from 2,496 gallons in 1988 to a projected 1,080 gallons in 1989. These decreases are mainly due to the changes in equipment and operating procedures in the paint shop, but are also partially due to changes in inventory and a decrease in production rate from 1988 to 1989.

Waste paint decreased from 42 tons in 1987 to 31 tons in 1988, and to 17 tons in 1989. These quantities include both waste paint and still bottoms (stills were not installed until October 1988). Currently, still bottoms are being generated at a rate of about 5,000 pounds per year from the batch distillation of the solvent used for cleaning oil based paint equipment, while recycling about 1,000 gallons (an estimated 8,000 pounds) of paint solvent. Assuming that the still bottoms and recycled paint solvents can be added to the current waste generation rate (17 tons/yr) to obtain the amount of paint waste generated with only the addition of proportional paint mixers and increased transfer efficiencies from electrostatic spray nozzles, the waste generation rate would have been about 24 tons (14 tons plus 2.5 to 3 tons for still bottoms plus 4 tons for recycled solvents), the waste reduction is about 7 tons per year. Again, this calculation does not consider decreased production rate.

Only polyurethane solvent (for oil-based paints) is currently being recycled in the stills. When distilling the water based paint solvent which contains isopropyl alcohol and xylene, the recycled solvent separates into two layers, a water layer and a solvent layer. Even when the water layer is removed by draining water contained within the solvent it prevents the solvent from being reused for thinning or cleaning. Potentially the water can be

separated with a similar approach used for GD's Freon stills. This method would have a water separator upstream and a molecular sieve downstream of the stills for improved water separation.

Economic Evaluation Results

The installation cost of the robotic painting system was $1,400,000. This system included a parts conveyor, computer-controlled robots, electrostatic spray guns, proportional paint mixing, and cleaning solvent collection equipment. The disposal of 42 tons of waste in 1987 would have cost about $73,000 at the current disposal rates of $420/drum plus $7,000 per truckload for transportation (80 drums). The disposal of 21 tons in 1989 would be about $36,500, for a savings of about $36,500. The payback period from a waste-disposal standpoint alone would be almost 40 years. This substantially overstates the payback period, however, because the savings in labor costs from painting and waste disposal and any decrease in reject parts are not included. The information is considered company sensitive and was not available.

The two solvent stills were installed at a cost of $14,000. These units are currently being used to recycle 1000 gallons per year of cleaning solvent (polyurethane thinner), resulting in $1500 in purchase savings and $2500 in disposal savings, for a total savings of $4000. The estimated payback period for this equipment, therefore, is 3.5 years. This estimate does not include increased labor costs to operate the equipment or decreased hazardous waste handling costs.

SAMPLING/ANALYSIS

Air samples were collected in the general area around the paint shop to verify low concentrations of VOCs. No previous data were available to compare the results.

Air samples were collected using charcoal tubes on a table near two paint spray booths, on the floor just outside the robotic paint booth, and on a lower shelf next to a small spray booth just inside a drive-through door leading to the outside. Figure 4-2 illustrates these locations. The sampling results are summarized in Table 4-1. Only 1,1,1-trichloroethane (TCA) was detected at all three sampling locations. Concentration levels ranged from 0.2 to 1.6 mg/m^3, or 1.7 to 12 mg/m^3 for an 8-hour time-weighted average (TWA). The OSHA TWA limits for 1,1,1-trichloroethane are 1900 mg/m^3, well above the levels detected in the paint shop. Trichlorotrifluoroethane was detected on the two charcoal tubes nearest the floor. Measured levels were 2 and 6 mg/m^3, or 17 and 48 mg/m^3 for the 8-hour TWA. This can be compared with the OSHA TWA limit of 7600 mg/m^3 for trichlorotrifluoroethane. It is interesting to note however, that TCA and trichlorotrifluoroethane are not used in the painting shops. Thus these samples measured fugitive emissions from other work areas.

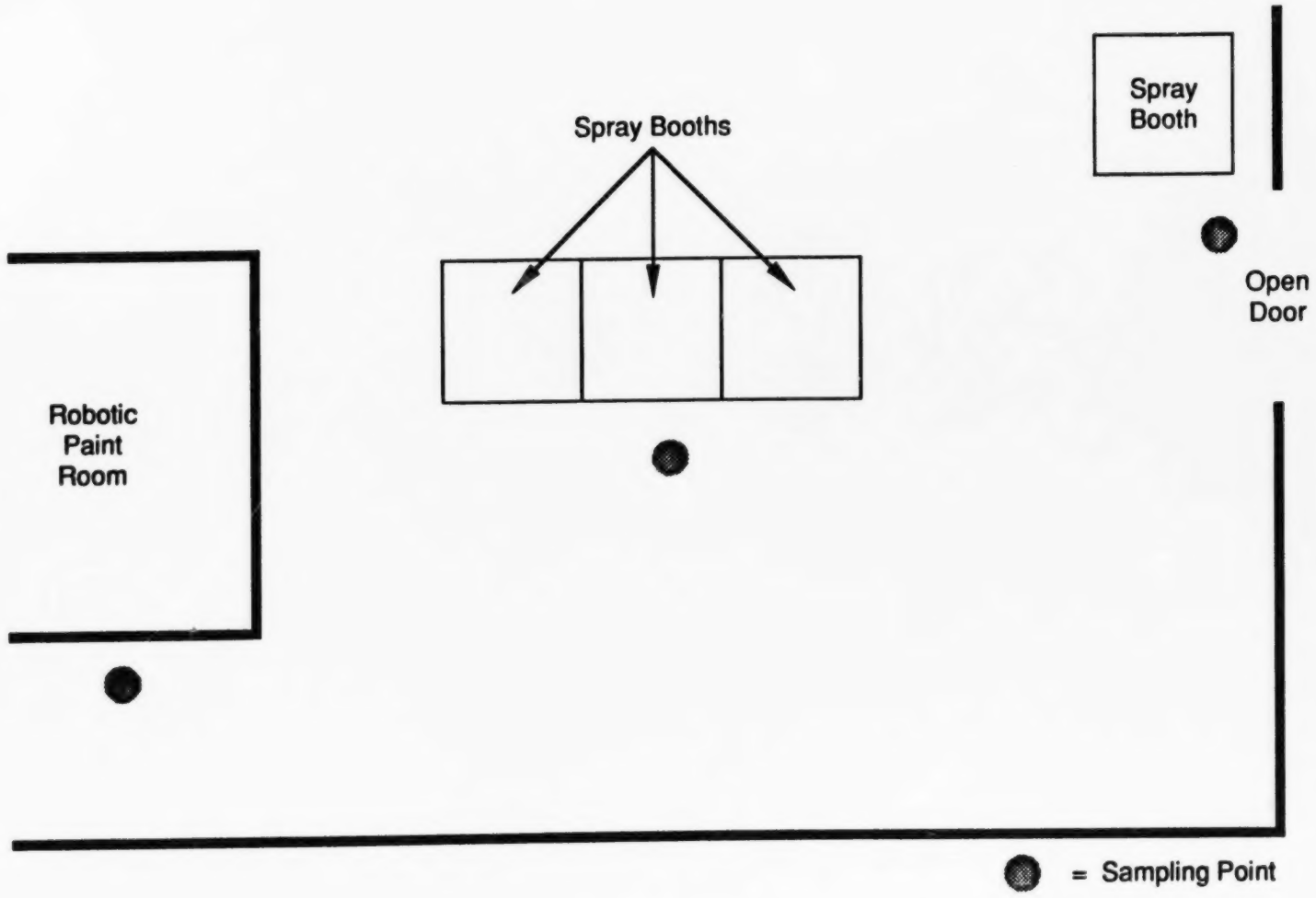


Figure 4-2. Relative locations of tenax and charcoal tube air samples for the paint facility.

TABLE 4-1. SUMMARY OF AIR SAMPLING PERFORMED IN THE GENERAL DYNAMICS PAINT SHOP

	Charcoal Tube 1	Charcoal Tube 2	Charcoal Tube 3
Location	On table near two paint booths and exterior door	On lower table near small booth	On floor near robotic paint booth
Distance from floor, ft	3.5	1	0
Quantity in sampled air, μg			
1,1,1-Trichloroethane	6	10	26
Trichlorotrifluoroethane	0	100	100
Pump readings			
Begin		991,219	106,081119,286
End	1,033,000	188,856	155,140
Pump flow (difference)	41,781	82,775	35,854
Pump run time, min	339	334	333
Calibration, ml/min	56.9	139.6	49.9
Flow, m^3	0.019	0.047	0.017
Concentration, mg/m^3			
1,1,1-Trichloroethane	0.3111	0.2145	1.5647
Trichlorotrifluoroethane	0.0000	2.1447	6.0180
8-hour TWA			
1,1,1-Trichloroethane	2.488	1.716	12.518
Trichlorotrifluoroethane	0.000	17.158	48.144
TWA limits, mg/m^3			
1,1,1-Trichloroethane	1900		
Trichlorotrifluoroethane	7600		

Quality Control

For the air samples, surrogate recoveries from compounds spiked on charcoal tubes from the field and a laboratory blank were all within the target range of 60 to 145 percent as shown in Table 4-2.

TABLE 4-2. SURROGATE RECOVERIES FOR CHARCOAL TUBE BLANKS

	Surrogate recovery, %		
Blank No.	d4-1,2-dichloroethane	db-toluene	p-Bromo-fluorobenzene
Laboratory blank	91	92	92
GDP-C1	79	82	83
GDP-C2	92	93	95
GDP-C3	88	94	96
GDP-CB2	88	92	94

CONCLUSIONS

The paint facility with proportional paint mixing, robotic controlled electrostatic sprays and cleaning solvent collection equipment appears to be operating well and is reducing worker exposure and waste paint considerably over previous levels. The main problem area is the waste solvent collection process, where problems need to be worked out in separating water from solvent in the case of the water based primer cleaning solvent recycling. This problem had led to a reluctance to utilize the solvent recycled from the water based primer cleaning because of its poor quality. Only polyurethane thinner solvent from cleaning paint equipment is currently recycled.

Detailed costs were not available to develop a comprehensive economic evaluation of the waste minimization methods applied to the production paint shop. The payback period of almost 40 years, calculated on the overall investment of $1.4 million is substantially overstated because labor costs savings from paint and waste disposal and decreases in reject paints were not available. Payback for the solvent stills is only about 4 years, but would be less if all cleaning solvent was being recycled.

The paint shop modifications decreased overall paint waste generated by at least 50 percent from 1987 to 1989. With additional funding to solve the water contamination problems in the recycling of water based primer cleaning solvent, confidence in the quality of the recycled solvent should return. The disposal of used cleaning solvents from the paint shop will eventually be eliminated which will decrease solvent purchases and the cost of solvent disposal.

The transferability of the waste reduction technologies in the paint facility to other industries could be prohibitive given the substantial capital investment required, unless the company had sufficient paint cleaning solvent disposal problems and could afford the cost. Parts of the system such as the electrostatic sprays and solvent stills are inexpensive and could be easily transferred to other industries.

SECTION 5

BEAD-BLAST PAINT STRIPPER

TECHNOLOGY DESCRIPTION

The plastic bead-blast paint stripper at General Dynamics was installed in June 1988 to replace methylene chloride stripping. Reusable plastic beads are used in this mechanical stripping operation, which is similar to sand blasting. Paint is stripped from the hangers used to hold parts being painted in the paint shop and from parts having paint defects.

The plastic bead-blasting booth is a Pauli and Griffin Pram Machine approximately 3 ft by 3 ft by 3 ft, and uses size 20- to 30-mesh Poly Plus beads. The unit is used only on an as-needed basis, generally a few hours per week.

Waste generated during the operation of the plastic bead-blasting unit consists primarily of paint chips with a small amount of spent plastic beads which is sent offsite for incineration. Stripping by methylene chloride resulted in about 10,000 pounds per year of toxic solvent contaminated with paint sludge, which also was sent offsite for incineration. Figure 5-1 is a schematic of the bead-blast paint stripper.

TECHNICAL/ECONOMIC EVALUATION

Objectives

The objectives of the plastic bead blasting evaluation included the following:

1) Establishment of a material balance around the bead blasting operation, if possible, using plant-supplied data on input and output of plastic beads and paint. The paint chips are mixed in with the other wastes at the plant before incineration, and preliminary indications from General Dynamics were that the amount of paint chips sent out for incineration would be difficult to ascertain. If so, it was decided that an estimate of paint chips discarded annually would be made after interviewing plant personnel.

2) Fugitive dust emissions around the bead blaster were reported to be negligible during operation, as the system is completely closed. Thus, no air sampling was planned.

3) An economic analysis of the bead blaster was planned. Annual operating costs, which are primarily the cost of incinerating the paint chips vs. the cost of disposing of methylene chloride, were to be calculated.

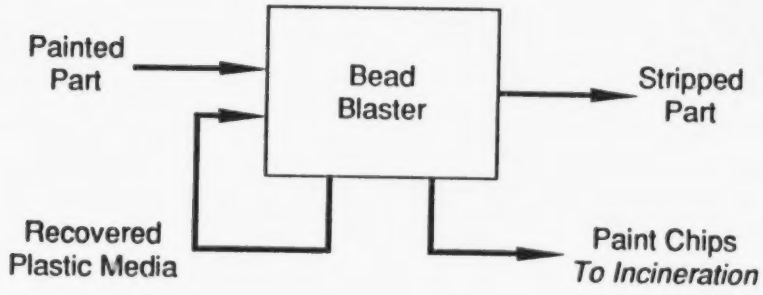


Figure 5-1. Schematic of production paint shop bead blast paint stripper.

Technical Results

A material balance around the bead-blasting unit was not possible from the information available from plant personnel and operating records. No operating records are kept with respect to when the unit is operating or how many pieces are stripped. The unit is used on an as needed basis and reportedly only a few hours per week. During the plant visit, the beadblasting unit was not operating.

Air sampling was not conducted during the General Dynamics site visit because fugitive dust emissions around the unit were reported to be negligible. This assumption was reasonable considering the parts subjected to bead blasting are enclosed during paint stripping. In addition, during an initial visit to General Dynamics, the area around the bead-blast unit was free of debris and paint chips. Fugitive emissions can occur, however, when parts are stripped without tightly closing the access door, when parts are being placed into or removed from the unit, when cleaning out the stripping chamber and cleanout drawer, and when dust on the floor is reentrained in the air.

Economic Evaluation Results

The bead-blast paint stripper was installed at a cost of $18,000. This system eliminated the disposal of about 10,000 lb/yr with a cost of approximately $10,000. Although the waste from the bead-blasting unit has not been quantified, plant personnel report that there is noticeably less waste when stripping with the bead-blast unit than with methylene chloride. A recent study* indicated that waste generated from plastic bead blasting was about one-half the volume as that generated by methylene chloride stripping. Both the methylene chloride and bead-blast waste are disposed by incineration resulting in waste disposal costs of $10,000 for methylene chloride and $5,000 for bead-blast waste. Based on this cost savings of $5,000 for disposal of the paint chips and spent plastic beads when compared to methylene chloride disposal and the installed capital cost of $18,000 of the bead-blast unit, the payback period from the cost of waste disposal alone, would be about 3.6 years for the bead-blasting unit. This, of course, does not consider differences in operator time, maintenance requirements, and stripping materials which will vary depending on parts being stripped, whether the methylene chloride stripping is being done by spray-on or dip tank methods, skill of the operator, and recovery of the stripping materials. Because of the unavailability of operating data and the infrequent use of the beadblasting unit, these factors could not be used to develop a comprehensive economic evaluation.

CONCLUSIONS

The plastic bead blast system appears to be operating as planned although no operating records are kept on the operation of the unit or how many pieces are stripped. The unit apparently does not see much action. Although it was originally thought that no fugitive emissions would occur around the unit, some emissions apparently can occur when the access door is not closed tightly during operating or during cleanout procedures with reentrainment of dust.

A payback of about 3.6 years was estimated based on literature data from a similar operation, but the lack of operating data on the unit precluded a more accurate economic evaluation. The use of the bead blaster, however, appears to be fairly cost effective and completely eliminates the use of methylene chloride. The technology is inexpensive and is easily transferred to other industries and small companies.

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* Balasco A. A., et al. Demonstration Testing of Plastic Media Blasting (PMB) at Letterkenny Army Depot. Prepared by Arthur D. Little, Inc., for U.S. Army Toxic and Hazardous Materials Agency under Contract No. DAAK11-85-0008. Aberdeen Proving Ground, MD. January 1989.

SECTION 6

FREON RECOVERY STILLS

TECHNOLOGY DESCRIPTION

Three Freon recovery stills manufactured by Recyclene were installed in December 1988 to collect and distill waste from solvent degreasing operations throughout the GDPD facility (Figure 6-1) at a cost of $240,000 plus $40,000 for add-on equipment to address operating problems (discussed in Section 3). Recovered solvent from these stills is tested and reformulated under a quality assurance program to ensure that it meets manufacturer's original product specifications before being returned to material stores for reissue to production operations. Still bottoms are sent out for incineration.

Prior to the installation of these stills, a single on-line Freon recovery still was installed in November 1985 to extend the life of Freon used in conveyorized cleaners. This extended the solvent changeout period to once per year and saved 35,000 lb annually in Freon purchases. This still is not included in the analysis.

Other changes in operation procedures to reduce degreaser solvent changeouts have resulted in a substantial reduction in Freon purchases. These operating changes were instituted beginning in April 1987 after GDPD completed a survey of all degreaser operations. The program objectives were to standardize all solvent cleaning operations through employee education, improved operating procedures and a solvent quality assurance program using vendor recommendations and operator input. The degreaser survey revealed that the solvent was changed every 1 to 7 days based solely on a visual analysis by the user. A quality assurance laboratory analysis program was implemented which extended the time between changeouts to 7 days, then 14 days, and finally 30 days. At the same time, the number of solvent types used was reduced from five to one over a 6-month period ending in February 1988. Manufacturing Process Specifications were changed to restrict change out authorization to the Process Quality Assurance Laboratory to assure that proper justification for changeouts was provided. To further reduce the changeout frequency, a moisture removing desiccant was added to each degreaser which resulted in an extended use period of 30 days. A standardized operating procedure was developed to reduce evaporative losses based on manufacturer recommendations and was included in all operating instructions as well as posted on signs at each unit. Operator training was completed by all user departments, equipment operation checked, and preventive maintenance procedures updated. Standardized equipment specifications were also developed to further reduce evaporative emissions on new degreasers and ensure compliance with California South Coast Air Quality Management District

regulations. As a result of the control measures implemented, the Division experienced a 35 percent reduction in 1988 cleaning solvent purchases from 650,000 pounds to 421,000 pounds.

The 1988 level of 421,000 lb of Freon purchases provides the baseline for the technical and economic evaluation discussed next for the three new Freon stills.

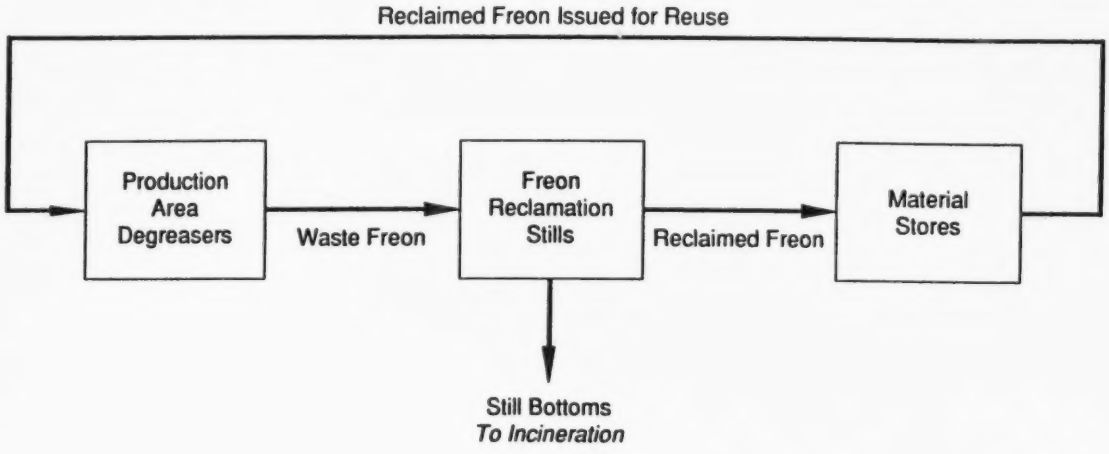


Figure 6-1. Freon solvent recovery stills.

TECHNICAL/ECONOMIC EVALUATION

Objectives

The objectives of the Freon recovery stills evaluation were as follows:

1) Determination of the amount of Freon solvent reclaimed by reviewing plant records on Freon purchases and solvent sent offsite before and after installation of the Freon stills. The volume of still bottoms sent out for incineration and associated costs were also to be determined, based on plant operating records.

2) An economic analysis of the Freon still recovery system capital, annual operating costs/credits, and payback was planned.

Technical Results

Testing of the Freon recovery stills in 1988 indicated that the distillation process was working but that the Freon being recycled was

contaminated with alcohol and water, which degraded the quality of the recovered product. GDPD has installed separators and molecular sieves to dry and remove water and alcohol from the Freon after its distillation and recovery. These additions to each still cost $13,000 plus installation but allow the Freon recovery to proceed as planned and produce a quality recycled solvent.

Economic Evaluation Results

Reduction in Freon purchases through 1988 have primarily come through improved operation procedures such as extended changeout times for Freon, and reduction in evaporative losses. A baseline of 421,000 lb of Freon for 1988 is used to calculate reductions in Freon usage attributable to the use of the three Freon stills, which are assumed to be utilized at full capacity for the first time in 1989. The following calculations were performed to calculate simple payback for the installation of the three Freon stills:

Capital cost:		$270,000
Annual operating cost:		negligible
Estimated 1989 Freon production adjustment @ 15%:	357,850 lb	
Evaporative and dragout Freon losses @ 37.5%:	134,194 lb	
Amount of Freon processed for recycling:	223,656 lb	
Still bottoms from Freon recycling @ 5%:	11,183 lb	
Avoided purchases (amount recycled) of Freon:	212,473 lb	
Cost savings from avoided Freon purchases @ $1.64/lb:		$348,456
Cost of still bottoms incineration @ $500/drum & 715 lb/drum:		$7820
Cost savings from avoided Freon disposal:		$148,583
Total cost savings:		$489,219
Payback:	$270,000/$489,100 = 0.55 years	

This is a minimum payback number that is based on recycling all of the Freon that is not lost through evaporation and dragout losses. If less Freon is recycled, the payback period would increase but at worst, it would only increase to about 1 year. Notwithstanding the technical problems that have been encountered in recycling the Freon, this is a very economical waste minimization technique.

CONCLUSIONS

The use of the Freon stills to recycle all Freon solvent used at GDPD has just hit full operation in 1989. Technical problems with water and alcohol contamination have apparently been solved and the stills are able to produce a quality product.

An economic evaluation on what appears to be accurate plant information reveals a payback period of less than one year. Overall, the use of the Freon recovery stills is a successful and very cost-effective waste minimization technology; one that could be easily transferred to other industries and to smaller companies.

REFERENCES

1. Apel, M. L., et al. Guidance Document for the WRITE Pilot Program with State and Local Governments, U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Cincinnati, Ohio, 1988.

2. California Department of Health Services. The Fourth Biennial Report: Economic Implications of Waste Reduction, Recycling, Treatment and Disposal of Hazardous Wastes, State of California, Toxic Substances Control Division, Sacramento, California, 1988.

3. General Dynamics Co. Pomona Division, Pomona, California. Private Communication and Videotape, 1989.

4. PEI Associates, Inc. Model Quality Assurance Plan for the WRITE Program with States: Evaluation of Pollution Prevention Technologies at General Dynamics, Pomona, California Facility. July 1989.

APPENDIX

PHOTOGRAPHS OF WASTE MINIMIZATION TECHNOLOGIES AT GENERAL DYNAMICS - POMONA DIVISION

PROCESS CHANGE PHOTOGRAPHS

A-1. Printed Circuit Board Plating Line and Overview

A-2. Printed Circuit Board Plating Line Transporter Hoists

A-3. Proportional Paint Mixers

A-4. Robotic Paint Line Control Room

A-5. Robotic Paint Equipment Programing

A-6. Robotic Paint System Electrostatic Primer Application

A-7. Robotic Paint System Electrostatic Topcoat Application

A-8. Bead Blast Paint Stripper

RECOVERY EQUIPMENT PHOTOGRAPHS

A-9. High Mass Transfer Copper Electrowinner

A-10. Reclaimed Copper High Mass Transfer Electrowinner

A-11. Short Bed Ion Exchange Copper

A-12. Paint Shop Solvent Recovery Stills

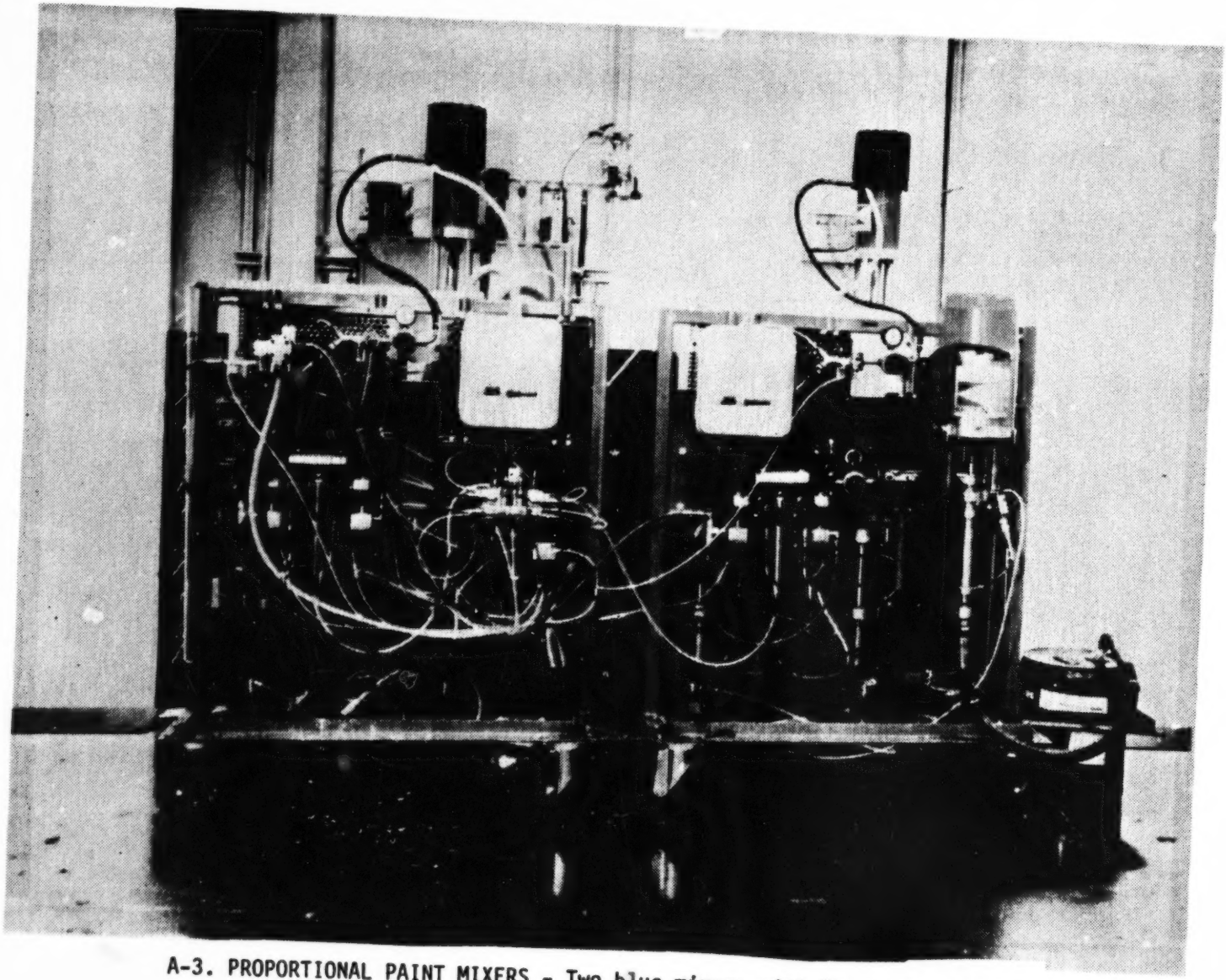
A-13. Reclaimed Solvent & Paint Sludge

A-14. Freon Recovery Still

A-1. PRINTED CIRCUIT BOARS PLATING LINE AND OVERVIEW - Picture of diagram "Electronic Fabrication"

Reproduced from
best available copy.

A-2. PRINTED CIRCUIT BOARD PLATING LINE TRANSPORTER HOISTS - two orange hoists in frame



A-3. PROPORTIONAL PAINT MIXERS - Two blue mixers with "Kremon" cylinder

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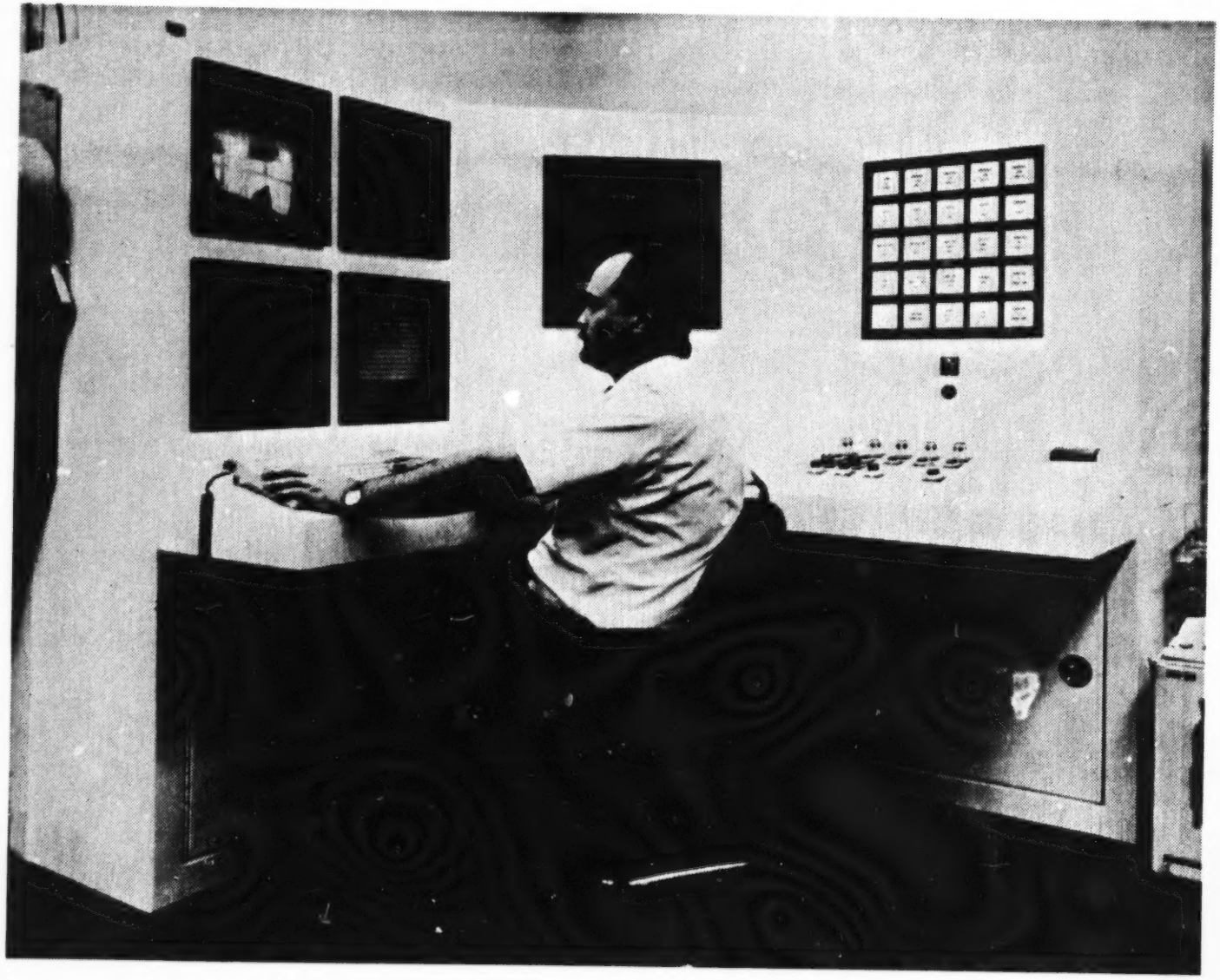
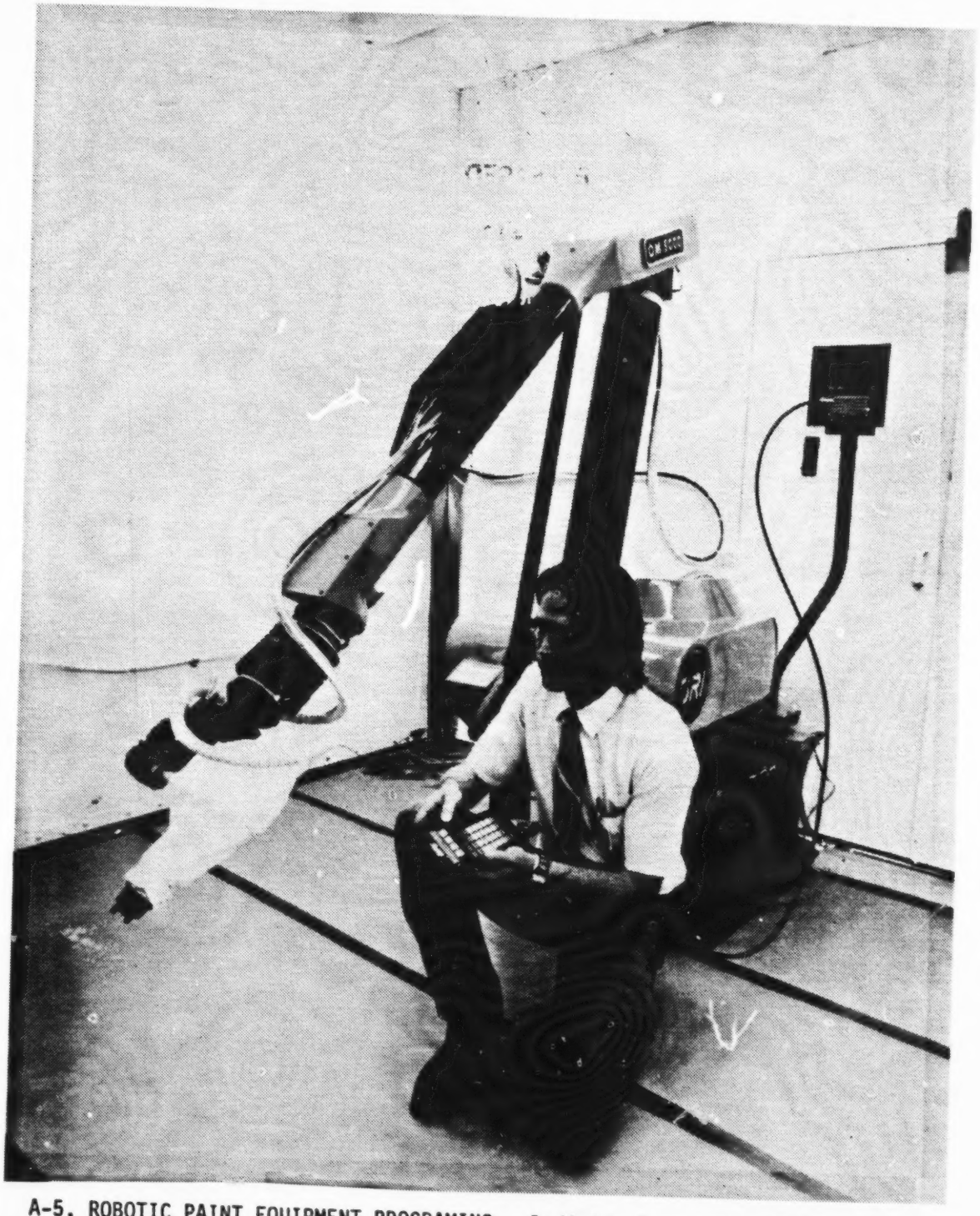
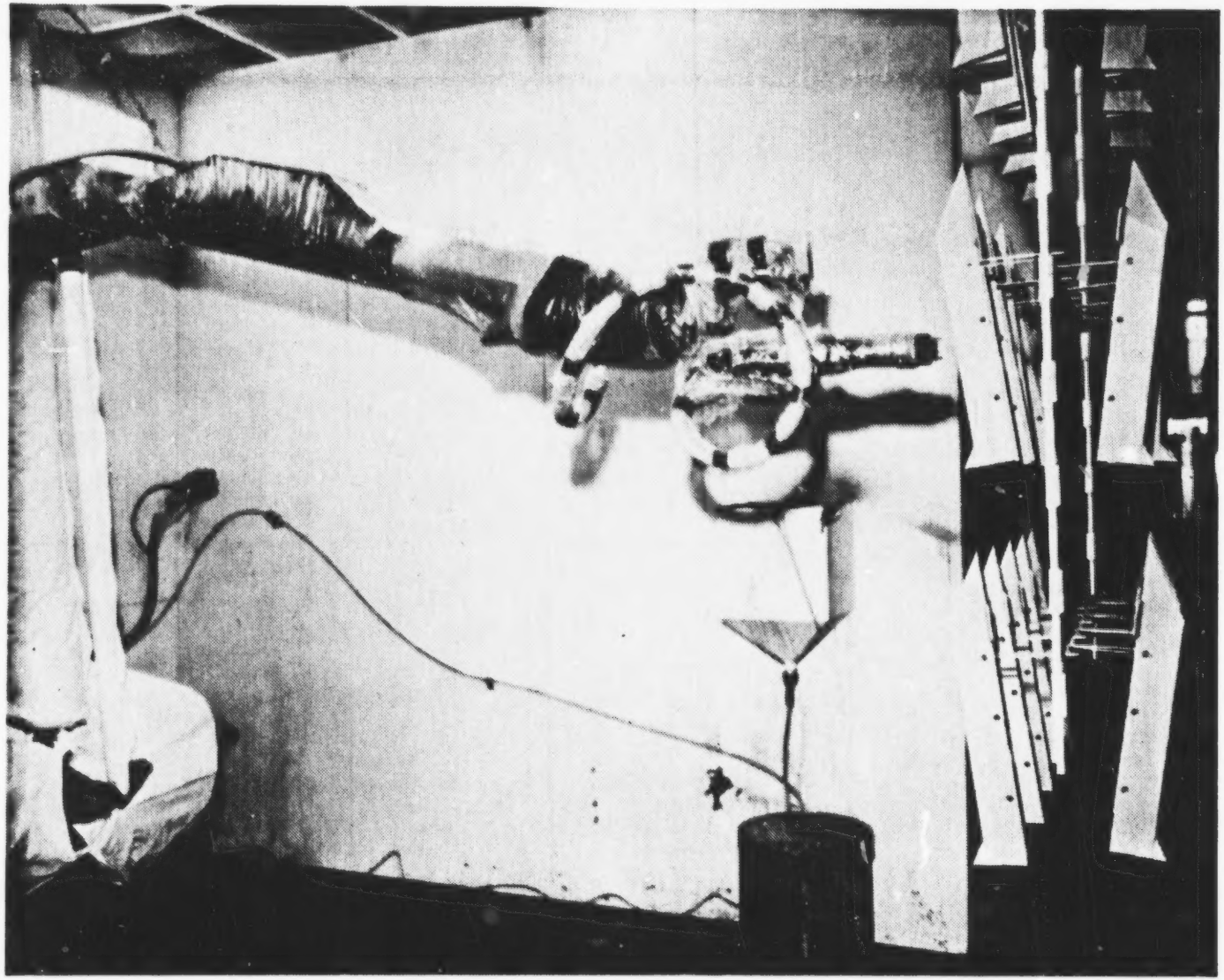
best available copy.



A-4. ROBOTIC PAINT LINE CONTROL ROOM - Operator sitting in control room



A-5. ROBOTIC PAINT EQUIPMENT PROGRAMING - Individual operating OM500 yellow robot



A-6. ROBOTIC PAINT SYSTEM ELECTROSTATIC PRIMER APPLICATION - wrapped extended arm of robot (with red/white coil) spraying white panels

A-7. ROBOTIC PAINT SYSTEM ELECTROSTATIC TOPCOAT APPLICATION - arm of robot used to spray white triangular materials

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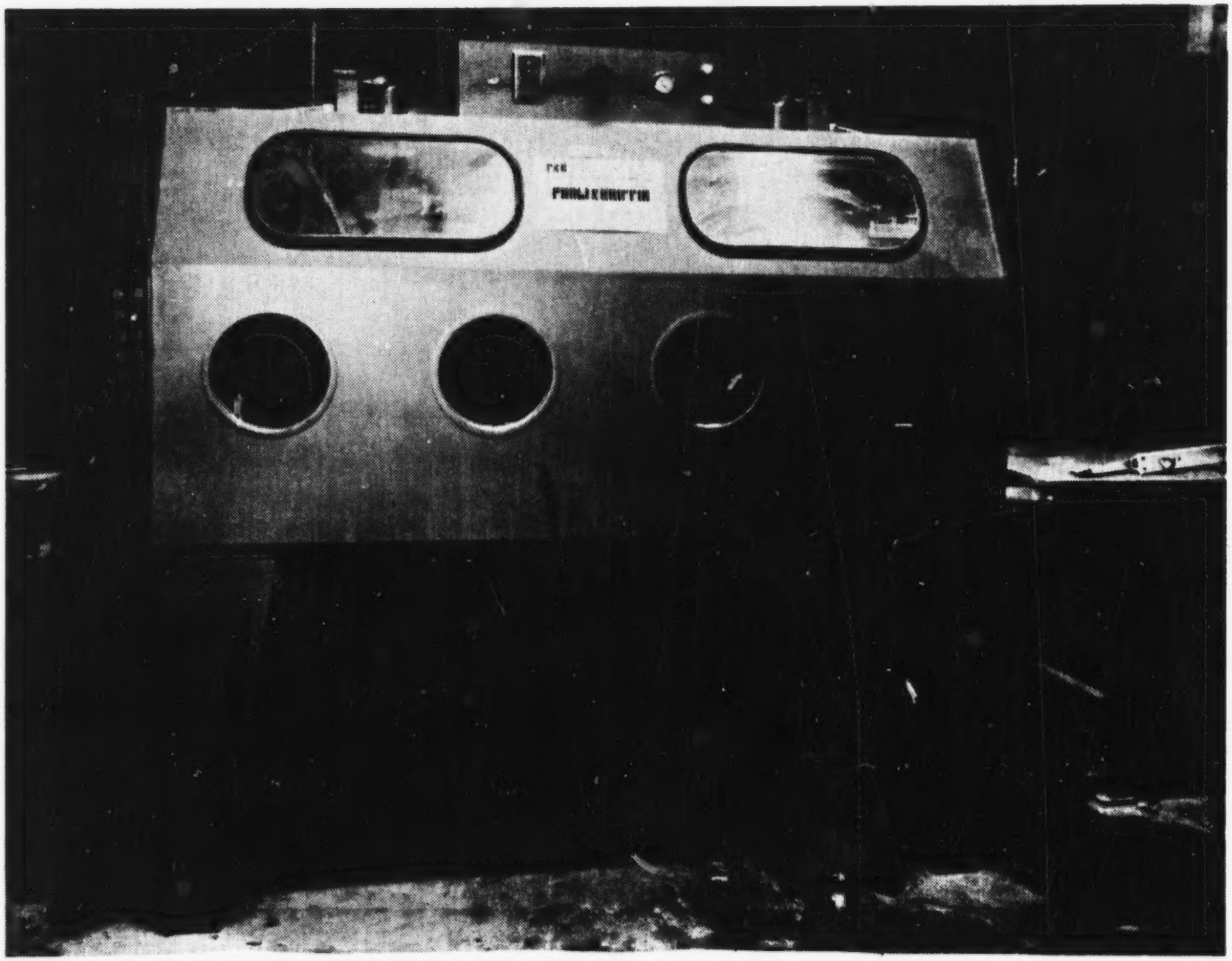
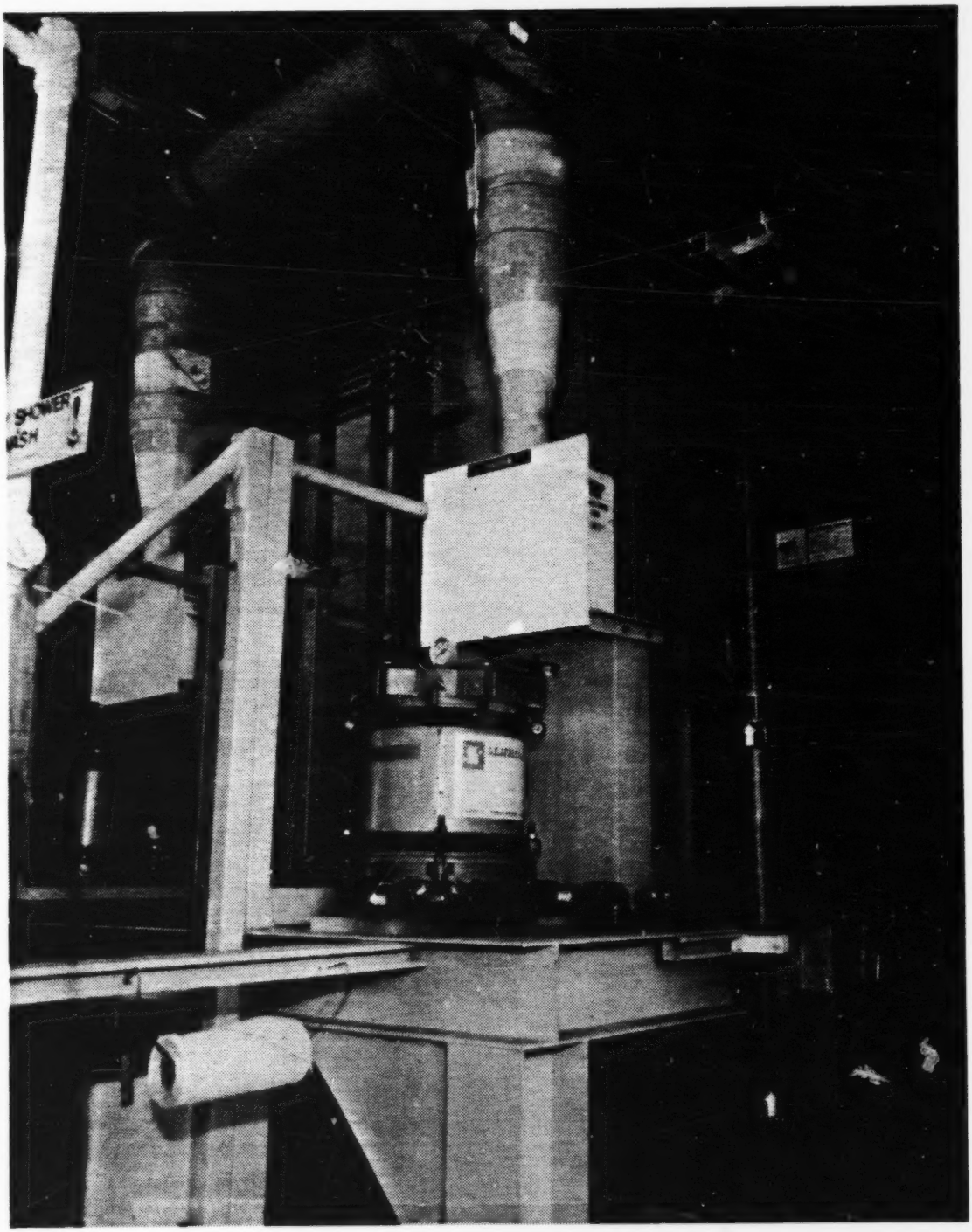


A-8. BEAD BLAST PAINT STRIPPER - blue horizontal bead blast machine (Pauli & Griffin) with two upper windows



A-9. HIGH MASS TRANSFER COPPER ELECTROWINNER - electrowinner with acid tank in center of photo, vacuum tube in upper photo, power supply to right, safety shower release to left

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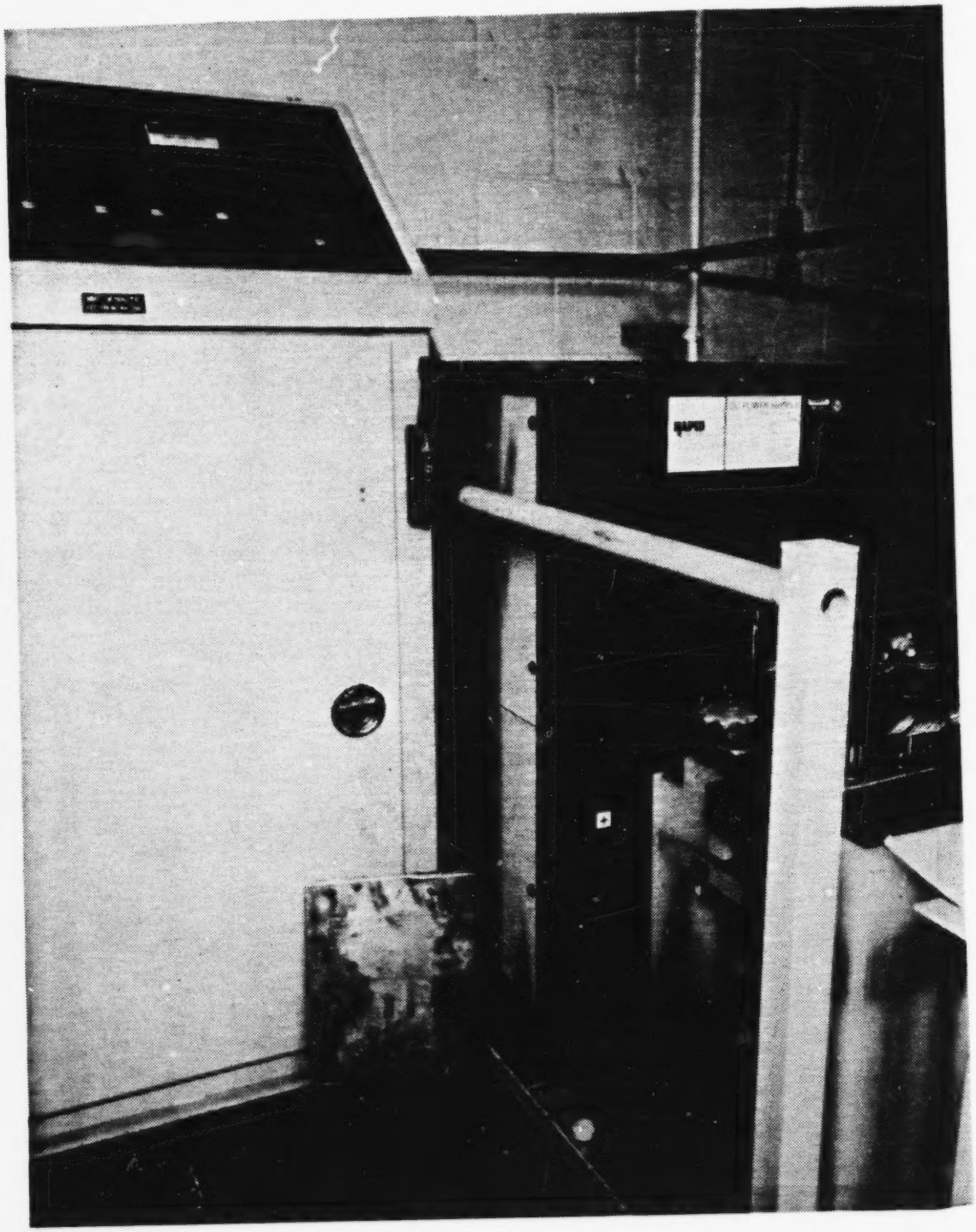
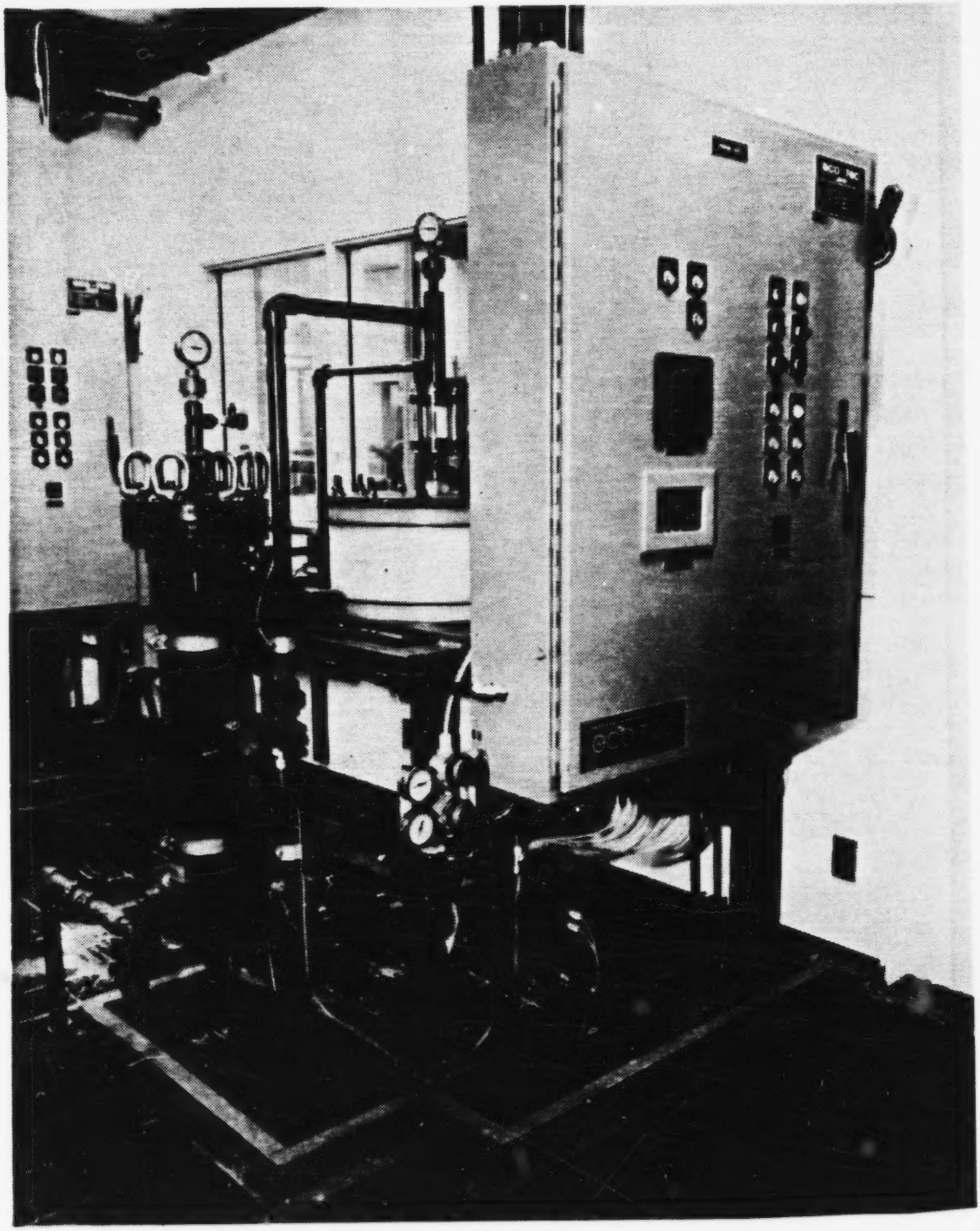


A-10. RECLAIMED COPPER HIGH MASS TRANSFER ELECTROWINNER - white electrowinner to left with blue power supply to right, plat of copper in center bottom of photo



A-11. SHORT BED ION EXCHANGE COPPER RECOVERY - Eco-tec ion exchange systems with short bed to left and behind grey control panel box. System mounted on blue metal track.

A-12. PAINT SHOP SOLVENT RECOVERY STILLS - photo of blue "Little Still" with several red cans at base.

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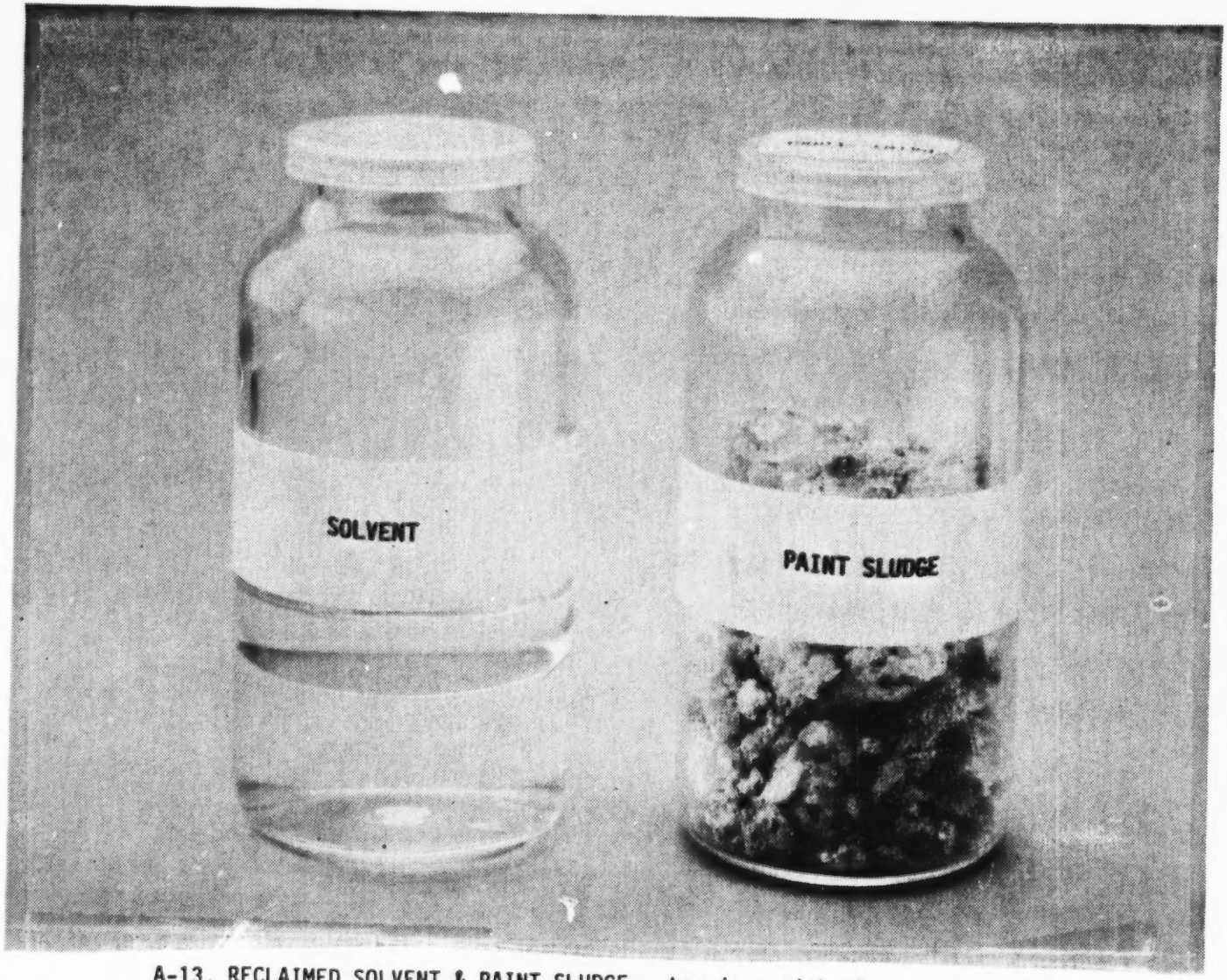
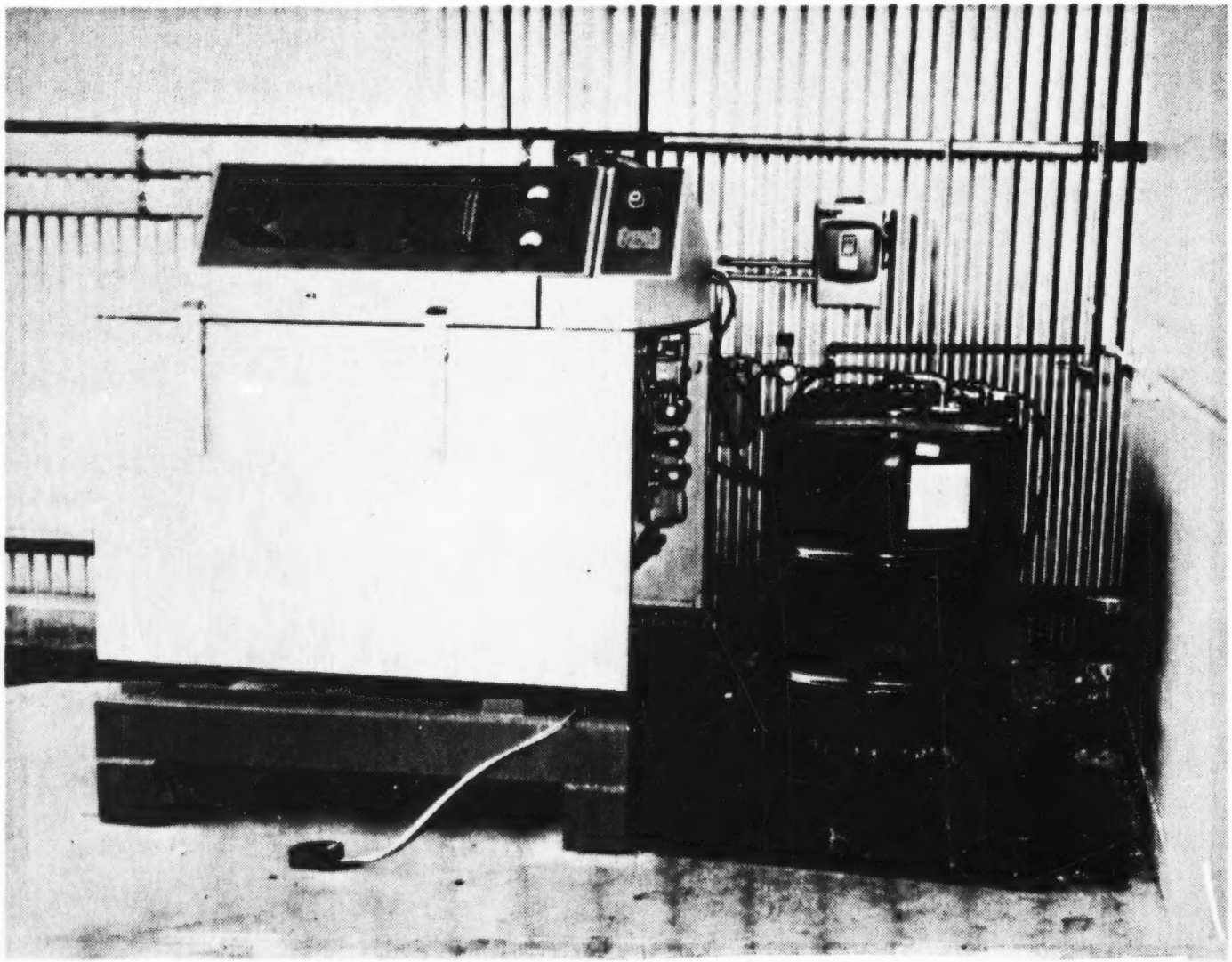


A-13. RECLAIMED SOLVENT & PAINT SLUDGE - tow jars with clear solvent and white/grey paint sludge



A-14. FREON RECOVERY STILL - "S-35" blue and white unit with green drum to left.